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RICE AND RICE DIETS

A Nutritional Survey

Washington, 1948



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RICE AND RICE DIETS

A Survey prepared by the Nutrition Division
of the Food and Agriculture Organization
of the United Nations

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Note

This survey was one of the documents prepared by the Nutrition Division for a committee of nutrition workers from countries in East Asia which met in Baguio, Philippines, in February 1948. In its report *The Nutrition Problems of Rice-eating Countries in Asia*, the Committee remarked that the survey would be valuable to nutrition research workers and others in rice-eating countries and recommended that it should be printed and given wide circulation after any necessary modification in the light of the Committee's discussions. The survey has been revised in accordance with this recommendation; it now contains numerous references to the report of the Baguio Committee and on all major issues adopts the same attitude as that report. The Committee is, however, not responsible for the survey in detail.

Introduction

Rice, wheat, and corn (maize) are the three main staple cereals of the world. Of the three, rice is quantitatively the most important since it is the staple food of more than half the human race. In the greater part of the geographical subcontinent of India, in Southern China, and in Southeast Asia generally, the daily diet of the people is based on rice. About two thirds of the total area under rice in the world is in China and India, and 90 percent of the world's rice crop is produced in the East Asian region. Smaller rice-producing areas are found in Africa, in the Carribean, and in North, Central, and South America.

This survey does not deal with current problems arising out of the present world shortage of rice or with measures to increase the production of rice, such as extended irrigation, the greater use of fertilizers, the introduction of high-yielding strains, and the elimination of pests and parasites, although these are questions of great importance at the present time since the need to increase supplies of rice is urgent. It is concerned primarily with the nutritive value of rice and rice diets and with ways and means of improving nutrition in rice-eating areas.

In the rice-eating areas of the world the amount of arable land available per head of population is usually small. This means that land must be devoted largely to crops that give a high calorie yield per unit of area, and rice stands high among such crops. Moreover, people in rice-eating countries usually depend for their existence almost entirely on agriculture in the broad sense of this term; industry on a large scale has not yet been developed. Rice eaters, therefore, are generally poor and cannot afford to buy, to any considerable extent, foods produced outside their own heavily populated areas. With poverty go illiteracy and ignorance, which make education in better food habits difficult. All these factors—with many others—play a part in depressing nutritional levels in rice-eating regions. The problem as a whole can be solved only by a general rise in standards of living; and a discussion of the far-reaching agricultural, industrial, and social developments which this would involve is outside the scope of the present report, in which emphasis is placed on more immediate measures for improving rice diets.

Rice, like all other cereals, is not a complete food, even in the "whole" unmilled state. That is to say, it does not contain sufficient amounts of all the nutrients needed for health. Its value is reduced by losses which take place between harvesting and consumption. Parallel losses in nutrients may occur in the case of wheat, but these are less important because wheat eaters

TERMS	DEFINITION	COMMENTS
Paddy*	Rice in the husk after threshing.	
Unhusked rice		
Rough rice		
Husked rice*	Rice minus its husk, with the germ, pericarp, and aleurone layers intact.	In many varieties of rice, the pericarp and part of the aleurone layer have a brown color; hence the term "brown rice" for husked rice. Other varieties, however, are white, so that the general use of the term "brown rice" is not appropriate.
Hulled rice		
Brown rice		
Silver-skin rice		
Cargo rice		
Whole rice		
Home-pounded rice*	Rice from which the husk and aleurone layer have been removed without use of power machinery.	The term "home-pounded" is preferable to "hand-pounded" since in some areas a pounding apparatus worked by the foot is used. Home-pounding usually removes the germ from most of the grains. The degree to which the germ, aleurone layer, and pericarp are removed depends on the vigor and duration of pounding.
Hand-pounded rice		
Undermilled rice*	Rice from which the husk, germ, pericarp, and the aleurone layers have been partially removed by power machinery.	The degree of milling referred to is variable. Usually most of the grains in undermilled rice are deprived of the germ, and part of the pericarp and aleurone layers.
Lightly milled rice		See below under polished rice.
Unpolished rice		
Milled rice*	Rice with its outer layers (germ, pericarp, and aleurone layer) removed by power machinery.	
Machine-milled rice		
Highly milled rice		
White rice		
Polished rice*	Milled rice treated after milling with polishing powders.	The term "polished" should be reserved for rice so treated. It is, however, sometimes applied to milled rice.
Coated rice		The chemical composition and vitamin content of milled rice and polished rice are approximately the same.
Broken rice	Husked, milled, or home-pounded rice, consisting of broken grains, smaller than three quarters of the whole kernel.	Various classifications of broken rice are used by the rice trade.
"Raw" rice	Rice which is not parboiled.	This term, which is commonly used in India, has no reference to cooking.
Parboiled rice	Rice obtained by pounding or milling from paddy which has been steeped in water, steamed, and subsequently dried.	Parboiled rice may be home-pounded or milled to various degrees in the same way as "raw" rice.
Rice husks*, hulls, or chaff	The outer woody covering of the rice kernels.	A by-product of the pounding or milling of rice.
Rice bran	The outer layers of the grain with part of the germ.	A by-product of the pounding or milling of rice. It often contains some husk.
Rice polishings	The inner bran layers, with part of the germ and a small percentage of the starchy endosperm.	A by-product of the milling of rice.

consume less cereal and a greater quantity of other foods than rice eaters and can therefore usually obtain from supplementary foods the nutrients which they require. Ways and means of ensuring that rice, as consumed, is as nutritious as possible is one of the main themes of this survey.

Typical rice diets contain too much rice and need to be supplemented to a greater extent by other foods. While such supplementation raises the fundamental issues referred to above, there remains the possibility of finding cheap foods of high nutritive value which can be produced under present agricultural and economic conditions. The latter part of the survey is largely devoted to this subject.

There can be no single method of approach to these problems which is appropriate in all rice-eating countries. Conditions differ from country to country and from region to region. On the other hand, experience gained in one country may be of great value in others, and a co-ordinated attack is likely to be more effective than piecemeal efforts. It will be one of the main tasks of FAO, in developing its program in Asia and other rice-eating areas, to stimulate and co-ordinate campaigns for improving the nutrition of rice eaters.

Definitions

Various names are applied to rice in the husk, rice at different stages of milling, and rice treated in various other ways before consumption. Confusion has frequently arisen through lack of uniformity in nomenclature. It will, therefore, be useful to define some of the terms used in this survey, and to indicate the nomenclature chosen.

Rice, when harvested, has a thick and "woody" husk of no food value for human beings. The grain itself consists of three parts: (a) the small germ¹ or embryo; (b) the outer layers of the grain which include the pericarp or seedcoat with the underlying aleurone layer; (c) the starchy endosperm. The germ, the pericarp, and the aleurone layer, which are richer than the endosperm in certain nutrients, are separated from the grain during milling or pounding to a greater or lesser extent depending upon the nature of the process.

A number of terms are defined on page 2. Those marked with an asterisk have, in general, been used in this survey.

¹The portion of the germ closest to the endosperm is known as the scutellum. In wheat and certain other cereals, the scutellum contains a high proportion of the thiamine (Vitamin B₁) present in the grain as a whole. The same is presumably true of the scutellum of the rice grain, but experimental proof of this is not yet available.

²These terms and definitions agree well with those recommended for tentative adoption by the Rice Study Group (1) and the Baguio Rice Meeting (2). However, terms suggested by the Rice Study Group which are only of commercial or local importance have not been adopted.

I Historical Background

Over sixty years ago, Admiral Takaki succeeded in eliminating beriberi from the Japanese Navy by partially replacing milled rice in the diet of the sailors by barley and wheat. The well-known researches of Eykman and Gryns in Java from 1890-1900 made it clear that beriberi is a food deficiency disease associated with the consumption of milled rice and that it can be prevented by replacing milled rice by husked rice or undermilled rice. Other workers, including Fraser, Stanton, Vedder, and Braddon made substantial contributions to the problem and a number of convincing human experiments were made. For example, when in 1910 undermilled rice was given to the Philippine Scouts in place of polished rice, the incidence of beriberi fell from 10 to 1 percent within a year, and beriberi disappeared from Javanese prisons when husked rice was introduced (3). It was observed that beriberi was rare in areas in which home-pounded rice was eaten. Braddon (4) was the first to draw attention to the fact that people who eat parboiled rice rarely contract beriberi, an observation of great importance.

During the early years of the present century, much attention was given to the problem of beriberi. Research clearly demonstrated the antiberiberi properties of undermilled rice and indicated a method of preventing the disease. But the substitution of milled rice by rice not deprived of its outer layers was found to be difficult in practice for a number of reasons. Many varieties of rice have a reddish-brown pericarp and aleurone layer, and when these varieties are undermilled or home-pounded, the color persists, whereas milling to a high degree removes the brown pericarp and produces white rice. The latter is considered more attractive in appearance and is preferred by the well-to-do even in areas where the greater part of the rice consumed is home-pounded. A certain "social status" is thus associated with white rice and those who are used to it are reluctant to change their habits. Moreover, undermilled rice (as well as parboiled rice) has a distinctive flavor and taste not possessed by white rice, and people accustomed to the latter do not relish the former.¹ Another important point is that the keeping qualities of milled rice are superior to those of husked or undermilled rice so that the general use of the latter raises various difficult problems of transport and storage. The rice milling industry is organized to produce

¹ The converse is also true: for example, during the Japanese occupation of the Far East, European prisoners of war became accustomed, after strong initial protests, to husked or undermilled rice. When they changed over to highly milled rice, they often found that they had developed a preference for undermilled rice and that milled rice appeared to be tasteless.

milled rice and has naturally resisted attempts to encourage the consumption of undermilled rice.

International and Intergovernmental Action

The recognition of the cause of beriberi led to its prevention in institutions and among communally-fed groups whose diet could be controlled. Relatively satisfactory methods of treating the disease (e.g., with extracts of rice polishings) were evolved. But little progress was made in preventing the occurrence of the disease among the general population in rice-eating countries. Discussions at meetings of the Far Eastern Association of Tropical Medicine in 1921 and 1923 in Batavia and Singapore respectively (5, 6) are illustrative of the situation at that time.

These discussions may be summarized as follows. Rice milling legislation was regarded as premature, since the problems involved had not been fully studied. The introduction of undermilled rice was not recommended because of the bad keeping qualities of this kind of rice and lack of knowledge about satisfactory storage conditions. No simple chemical tests to define degree of milling for legislative purposes were available; the so-called " P_2O_5 Test,"² used at one time to assess degree of milling and even vitamin content, was regarded as insufficiently reliable to be used as a basis of legislative measures. Again, it was felt that measures to prohibit or limit the production of milled rice would meet with resistance from the rice trade. The general conclusions were that more research was needed, that the use of milled rice should be "discouraged," and that educational campaigns against beriberi should be initiated.

As nutrition research developed it became clear that the milling of rice leads to losses of other nutrients besides the antiberiberi vitamin (vitamin B_1 thiamine) and that the prevention of beriberi was but one aspect of the problem. The League of Nations Intergovernmental Conference of Far Eastern Countries on Rural Hygiene, held in Bandoeng, Java, in 1937 (7) made no special reference to beriberi in the following resolution:

"The degree of milling to which rice is subjected is of vital importance in connection with the problem of nutrition throughout the East. In many countries, the poorer classes consume foods other than rice in small quantities, and it is very difficult, for economic reasons, to increase the amount of supplementary foods in the diet; in such circumstances, the nutritive value of the main article of food, which is influenced by the degree of milling, becomes of great significance. The Conference recommends that only undermilled rice should be supplied in Government institutions. Efforts

² This test is an estimate of phosphorus content. Since the germ and pericarp contain more phosphorus than the endosperm, there is a relation between the phosphorus content and degrees of milling, and hence vitamin content. The relation varies, however, with different varieties of rice and soil conditions, and does not hold in the case of parboiled rice.

to popularize the use of undermilled rice by education and propaganda should be increased. It deplors the increasing tendency of urban and rural populations in the East to consume highly milled rice. It strongly recommends that Governments should make a thorough investigation of the nutritional, commercial, economic, and psychological aspects of the problem, attention being given to the possibility of checking the spread of mechanical rice mills in rural areas, with a view to conserving the healthy habit of consuming home-pounded rice, and to means of making undermilled rice easily available everywhere for those who wish to purchase it."

Resolutions of this kind have not so far resulted in effective action, although attempts have been made here and there to teach people to eat undermilled instead of milled rice. The whole problem needs re-examination in the light of modern knowledge and the experience gained in certain countries. Research has shown that there are other ways of conserving the vitamin content of rice besides milling the grain in such a way that a sufficient proportion of the grain richest in thiamine and other nutrients is retained in the milled product: for example, parboiling and "conversion," which are considered later. The large-scale manufacture of vitamins in the pure state has created the possibility of adding to milled rice some of the vitamins which it lacks, or of introducing them into the diet in other ways. Further, it is becoming clear that, while the substitution of milled rice by rice of higher nutrient content would represent an important improvement, diets which are composed largely of rice of any kind are ill balanced and need to be supplemented adequately by other kinds of food. The cause of beriberi has been known for many years, but this knowledge has not yet led to the eradication of beriberi or to the general improvement of rice diets.

It is encouraging to note that soon after the war the attack on nutrition problems in rice-consuming areas was resumed on an intergovernmental and international scale. In May 1946, a nutrition conference (8) was convened in Singapore by the Special Commissioner in South East Asia; at this conference the nutrition problems of the region were considered in their short- and long-term aspects, and a number of useful recommendations were made. Attention was given to the nutritive value of rice diets and to their improvement.

The FAO Rice Study Group which met in Trivandrum, India, in May 1947 was more concerned with rice supplies than with the nutritional aspects of the rice problem; it recommended, however, that FAO should convene an expert committee to consider these aspects. The result was a meeting of the Nutrition Committee in Baguio, Philippines, in February, 1948. The report of this Committee, *Nutrition Problems of Rice-eating Countries in Asia* (9), deals at considerable length with ways and means of improving the nutritive value of rice and rice diets.

Steps which FAO will take to follow up the recommendations of this and other FAO committees concerned with rice, and the international machinery to be set up for this purpose will be briefly referred to in a later chapter. The point of interest here is that close attention is now being given to food and

nutrition problems in rice-eating countries and that this tendency should increase as the FAO regional program develops. The prospect that practical application will be given to the findings and recommendations of nutrition workers is more promising than it has been in the past.

II Nutrition of the Rice Eater

There is considerable medical and scientific literature dealing with this subject, and only a few salient points can be covered in this survey. In the rice eating areas of the world the general level of health—using the term health in its widest sense—is low in comparison with levels which have been attained in Western civilization. Among the criteria by which health in this broad sense may be assessed are mortality rates, expectation of life, the prevalence of disease, physical development, and working capacity. All these are influenced by nutrition, though nutrition is only one of the many factors concerned. More specific evidence of malnutrition can be obtained by investigating the incidence of food deficiency states, or by studying groups in the population, e.g., infants, children, and mothers, and applying certain methods and procedures—clinical, anthropometric, physiological, and biochemical—by which it is believed that state of nutrition can at least be approximately assessed. According to both these criteria, malnutrition is exceptionally prevalent among rice eaters. The good effect of supplementary foods of high nutritive value, such as milk, on the general health and development of children in rice-eating areas is also an indication of their normally poor state of nutrition.

Deficiency Diseases and States

Beriberi is the best known deficiency disease and has the longest history in the scientific sense. Table 1 gives some data about its incidence in certain countries in East Asia before the last war, and includes figures for the Philippines for 1946. According to the latter, the incidence of both adult and infant beriberi was greater in 1946 than in the prewar period. Recent data about beriberi in other countries are not available and it is difficult to obtain a clear picture of the present situation. The disease probably remains prevalent in Siam and in parts of China, India, and Malaya. Special emphasis must be laid on infant beriberi, a disease which is often unrecognized. Investigations in the Madras Presidency during the years 1939-45 showed that infant beriberi was much more common than had formerly been supposed and was responsible for a high mortality among infants. The disease in its acute form often leads to the sudden death of breast-fed infants during the second to the fourth month of life. If recognized it can be effectively treated by the timely injection of thiamine. The recovery, within 12 to 24 hours, of a thiamine-deficient infant after an injection of a few milligrams of thiamine can be very dramatic.

Apart from beriberi, numerous other deficiency states such as keratomalacia, stomatitis, glossitis, cheilosis, "burning-feet," and hepatic cirrhosis occur much

more frequently among rice eaters than among wheat-eating populations in general. Experience in prison camps in the East during the war has added considerably to our knowledge of deficiency diseases. A striking fact was the high incidence in these camps of neurological manifestations associated with deficiency of factors in the B complex of vitamins. Burning feet, retrobulbar neuritis, spinal ataxia, spastic ataxia and simple spastic paraplegia were among the conditions observed, in different combinations or separately. The first of these is known to be common among rice eaters of the poorer classes; the others also occur, but little is known as regards their frequency. Another important food deficiency state is liver damage leading to hepatic cirrhosis. Considerable attention is now being given in East and South Africa to this condition which may perhaps prove to be the most common of all food deficiency states in the tropics and the East.

A new picture of food deficiency disease appears to be emerging. Further research on this subject—which is greatly needed—is likely to provide more evidence of the ill effects of malnutrition on the human organism and to show that deficiency states which are still relatively unfamiliar are exceptionally prevalent among rice-eating populations.

Rice Diets

Typical rice diets are shown in Table 2. A characteristic of these diets is that rice supplies over 70 percent of total calories and that other foods, e.g. foods of animal origin, are present in relatively small quantities. Diets which contain so high a proportion of cereal are inevitably deficient in terms of modern standards of nutrient requirements. Even if the rice itself has not been seriously impoverished in nutrients by milling and during household preparation, rice diets remain defective because of their general composition. On the other hand, the high intake of rice makes the state in which it is eaten a matter of great importance—as was emphasized by the Bandoeng Conference in 1937; it is, for example, the factor which governs the incidence of beriberi, and it has some influence on the incidence of other deficiency states and diseases.

Apart from qualitative defects, insufficiency of calories is common in rice-eating regions; in other words, rice eaters often do not get enough food of any kind. This again adversely affects health. It must be emphasized that “enough food” is the primary need at present in many rice-consuming countries. This survey, however, is concerned with quality rather than quantity.

The above facts must be clearly understood in approaching the problem of improving the diet and state of nutrition of rice eaters. It is fallacious to ascribe differences in the health and state of nutrition of rice-eating and wheat-eating populations to differences in the nutritive value of the two cereals. These play some part, but more important is the fact that the consumption of wheat is usually associated with a high standard of living and that the diets of peoples whose staple cereal is wheat usually contain a greater variety of

other foods. In certain parts of the world, e.g., the Middle East, there are wheat-eating populations with a low standard of living whose diets resemble typical rice diets in their general composition since a high percentage of total calories is derived from the staple cereal. In respect of health and nutrition, these populations are closer to poor rice-eating groups than they are to the wheat-consuming communities of the West.

III Nutrient Content of Rice

Figures showing the average calorie yield and nutrient content of rice are reproduced in Table 3. Corresponding figures for two other cereals, wheat and corn, are included in this table; it will be seen that the three cereals, in the "whole" state, do not differ widely in nutrient content. The same is true of calorie value. Per unit of cultivated area, the calorie yield from rice is, however, usually much greater than the calorie yield from wheat (10).

Protein

The total protein content of rice is lower than that of most varieties of wheat and also than that of whole corn. On the other hand, rice protein is of good quality. The proteins of white (milled) rice compare favorably in amino-acid content with whole wheat and whole corn proteins. (See Table 4.) As judged by the "protein efficiency ratio," biological value, and net utilization figures, the latter are inferior to rice proteins (11), which have also been found to be superior to those of corn and oats in experiments with rats which gave a biological value of 86 for rice proteins at a 5-percent level of protein intake (12). A biological value of 80 for the proteins in polished rice, based on experiments with rats, has been reported from India, where considerable attention has been given to the study of rice proteins (13, 14). Similar experiments on rats elsewhere, with a 5-percent level of protein intake, indicated biological values of 73 and 72 for rice and corn proteins respectively, while the corresponding value was only 67 for wheat protein with an 8-percent level of intake (15). There is also evidence, based on rat experiments, that the proteins in polished rice are superior to the proteins of enriched wheat flour (16). Though very few human experiments have been made, it has been stated that rice flour protein has the high biological value of 83-86 for man (10). The digestibility of rice for human beings is considered in Chapter IV.

The results of two further relevant series of experiments with rats may be referred to here. The digestibility of proteins in both whole and milled rice has been found to be high, namely 96.5 and 98 percent respectively (17). The supplementation of rice with milk powder results in the better utilization of rice proteins; and the proteins of meat and fish, and soya bean in digestible form supplement those of rice (18).

Vitamins

The amounts of fat-soluble vitamins A and D in rice are negligible, as in other cereals. On the other hand, the vitamin E content of whole rice is considerable (19). Whole rice compares well with whole wheat as a source of

water-soluble vitamins, but wheat, especially high protein varieties, has a higher thiamine content. The riboflavin content of rice is low and vitamin C is practically absent. The average thiamine, riboflavin, and niacin content of 13 varieties of brown (husked) rice has been reported to be 3.55, 0.60, and 53.08 micrograms respectively per gram (15). The results of another investigation gave the following average values for 6 varieties: 4.2 micrograms of thiamine, 0.61 micrograms of riboflavin, and 47.2 micrograms of niacin per gram (20, 21). In experiments on reproduction and lactation in rats (22), rice and its by-products have been found to be good sources of pantothenic acid and pyridoxine, two other vitamins in the B complex. Husked rice was reported to be a better source of pyridoxine and inositol for rats than polished rice, but no significant differences were found with regard to pantothenic acid and p-aminobenzoic acid (23). Data on the vitamin content of rice are shown in Tables 3, 5, 6, 7, and 8.

Other Nutrients

Rice like wheat is a poor source of fat, and milling removes most of the fat from both cereals. Whole maize is richer in fat than whole rice or wheat. In its mineral content, rice resembles other cereals. It is poor in iron and calcium, and the calcium phosphorus ratio is unfavorable, being about 1:10 instead of 1:2 which has been regarded as the optimum ratio (15).

The general conclusion may be drawn that whole rice has nutritional properties approximately similar to those of other cereals in a similar state; it is somewhat superior in certain respects but inferior in others. Like all cereals it is not a complete food, and a diet containing only rice will not provide all the nutrients needed by human beings. Rice should, therefore, be supplemented by other foods which can supply additional amounts of protein, fat, and various vitamins and minerals.

Variation in the Nutritive Value of Rice as Grown

The available literature on the effect of variety, soils, fertilizers, and methods of cultivation on the nutrient content of rice is scanty. The most noteworthy observations on the relationship between variety and nutrient content have been reported from India where it was found that colored and coarser varieties contain larger amounts of proteins and minerals, particularly calcium and phosphorus (24). It has also been claimed that rice of colored varieties supports better growth in experimental animals than rice of uncolored varieties. Investigations in Java, however, have shown that the white varieties of rice, i.e., those with a white pericarp and aleurone layer, have much the same composition as colored varieties (25). Table 7 illustrates the variation in the vitamin content of different varieties of rice. A study of the B vitamins in rice and its milled products indicated slight differences when figures for individual varieties were compared with average values. Long-grain varieties, like Nira and Fortuna, were highest in vitamin content. Rexoro and Blue Rose occupied an

intermediate position, and the shorter grained varieties, Early Prolific and American Pearl, were lowest (20).

While the problem has not yet been sufficiently investigated, there is as yet no convincing evidence that certain varieties of rice are strikingly superior to others in nutrient content.

Little scientific work has been done on the effect of soil conditions on the nutritive value of rice. It was reported that rice grown on good soil contained higher percentages of soluble carbohydrates than rice grown on poor soils, whereas the latter contained considerably more ash (26). The following observations may also be quoted (27):

- (1) Rice grown on alkaline soil which contained large amounts of soluble and colloidal silica absorbed unusually large amounts of silica.
- (2) When the soil was high in soluble iron, which was largely in the ferrous state, the iron content of both heads and straw was also high.

The following experiments indicated that the chemical composition of the grain can be influenced by fertilizers (27);

- (1) The addition of nitrogen to a deflocculated silt loam soil increased the percentage of protein in the rice and the yield of rice.
- (2) The application of phosphorus to a soil deficient in this nutrient resulted in greater yield of rice and a higher phosphorus content on a percentage basis.

It has also been recorded that the cystine, tryptophane, lysine, arginine, and histidine content of rice can be increased by the use of fertilizers (15).

The following effect of irrigation on the nutritive value of rice has been reported: "Rice grown on puddled fields, in which a layer of water is always allowed to remain, has a nutritive value approximately one-third less than the same rice when grown under dry rain-fed conditions. The lower nutritive value of rice grown under wet conditions is due, in part at least, to its lower content of water-soluble vitamins." (28) These conclusions are based upon chemical analysis as well as rat-growth experiments. No attempt seems to have been made to confirm or extend them.

There is thus some evidence that the nutrient content of rice is influenced by variety, the kind of soil in which rice is grown, and by the application of fertilizers. The whole subject merits further investigation. The importance of variation in nutritive value due to these factors should not, however, be over-emphasized, since it is outweighed by the effect of processes to which rice is subjected after it has been harvested. This point is clearly expressed in the following statement:

"There are differences in nutritive values of different kinds of rice, and of the same rice grown under different conditions; but such variations of food value are of secondary importance in comparison with what can be attained by measures directed towards the conservation of the food value of the rice ordinarily produced." (10)

A similar position was taken by the Baguio Nutrition Committee.

IV Effect of Processing and Household Preparation on Nutritive Value

Milling

The structure and consistency of the rice grain are such that its outer layers can be easily removed by simple mechanical means. The production of refined white wheat flour is a more elaborate and expensive process than the production of white milled rice. During the last half century and more the mechanical milling of rice has steadily replaced the ancient and laborious practice of home pounding.

The technology of the commercial milling process cannot be considered in detail in this survey. It has been well described by others (15, 17). In commercial milling, which may include polishing (i.e., the use of polishing powders), the pericarp, aleurone layers, and germ are largely removed, and, with them, coloring substances; the resulting rice has, therefore, an attractive white color. It is less liable to infestation by insects and fungi, partly because of the loss during milling of nutrients which these organisms need as much as human beings do.

The degree of milling determines the amount of nutrients removed.¹ Protein, fat, vitamins, and minerals are present in greater quantities in the germ and the outer layers than in the starchy endosperm. The loss of these nutrients in milling is thus not in proportion to the weight of the bran and polishings removed. This is particularly true in the case of thiamine which is largely concentrated in the germ and the aleurone layers. While the loss of thiamine due to milling is the main cause of beriberi in rice eaters, the loss of other nutrients is also of considerable importance.

Another effect of milling must also be mentioned. The removal of the protecting seed coat or pericarp facilitates the extraction of soluble substances from the aleurone layers during washing. Washing of the whole grain with the seed coat intact leads to a smaller loss of water-soluble nutrients.

Losses of nutrients resulting from milling are illustrated in Tables 3, 5, 6, 9, 10, and 11. These may be very considerable. Thus, it has been reported that 76.3, 56.6, and 63.0 percent respectively of the thiamine, riboflavin, and niacin originally present in husked rice were removed during the milling process (15). The amounts of niacin, vitamin B₆, and riboflavin retained in finished rice, expressed as percentages of the amounts present before milling, were found to

¹ Here and in the following chapter the effect of milling, washing, and cooking on the nutrient content of raw rice is discussed; the greater part of the world's rice crop is eaten in the raw state. Parboiled rice, which is differently affected by these processes, will be considered separately.

be 21.5 for niacin, 25.6 for vitamin B₆ (pyridoxine), and 32.3 for riboflavin (29). Data about losses of pantothenic acid and pyridoxine will be found in Table 6. Special emphasis must be placed on losses of thiamine. The general effect of milling is to reduce the thiamine content of husked rice from 3.0-5.0 micrograms to 1.0 microgram or less per gram. In one series of experiments it was found that home-pounded rice still retained 2.4 micrograms per gram of thiamine, whereas milled rice contained only 1.0 microgram per gram, these being average figures based on the analysis of eight samples (30).

It has been reported that milled rice may contain 17 percent less protein than husked rice (17); the data in Table 9 show a reduction of 14.9 percent in protein content. The loss of protein due to milling is thus by no means negligible. The loss of fat, expressed on a percentage basis, is high, but since even husked rice contains little fat, it is not of much importance.

On the other hand, there is evidence that milling increases the digestibility of rice for human beings (Table 12). Husked rice is reported to be less digestible than milled rice because it contains more fiber and the cells of the pericarp and aleurone layers are less permeable to the digestive juices than the starchy parts of the grain. Undermilled and home-pounded rice come between husked and milled rice in respect of digestibility. It must be admitted, however, that the subject of the digestibility of rice at different stages of milling has been insufficiently investigated. It is possible that people who habitually consume home-pounded or undermilled rice can utilize it without appreciable losses during digestion. The problem is complicated by the fact that a sudden change from milled to undermilled rice may lead to intestinal upset and digestive disturbances, and the same may occur when raw rice is replaced by parboiled rice and vice versa. Studies of the digestibility of any kind of rice should thus be made on individuals who are fully accustomed to it.

In general, it is justifiable to conclude that differences in percentage digestibility are far outweighed by the actual losses of nutrients resulting from milling. This is particularly true of nutrients such as thiamine which are present in much higher concentration in the outer parts of the grain than in the endosperm.

The polishing of rice with special polishing powders gives the grain a glossy white appearance which appeals to some consumers and is also said to improve keeping qualities by offering some protection against insect attack. The practice is now less common than it was twenty or thirty years ago. Some polishing powders which have been used by the rice trade are harmful to the human body. In general, the use of polishing powders may be regarded as an unnecessary, and sometimes objectionable, refinement.

The Baguio Nutrition Committee drew attention to the losses of food (calories) which may occur as the result of technically inefficient milling. "As a result of the war, a large proportion of mills are in a worn-out state and require extensive repair and renovation. The processing of rice in such mills leads to extensive losses of human food, e.g., because of the high percentage of 'breakages.' The development of the rice-milling industry in the

East along improved and scientific lines would minimize losses of rice during milling. . . .”

Washing and Cooking

Rice is nearly always washed before it is cooked in order to remove dust, insects, husk, etc. Another reason for washing is the removal of fine starch particles from the surface of the grains which, if left, cause stickiness in the cooked rice. The intensity of washing varies from place to place, but since rice is nearly always contaminated with impurities, washing is rarely omitted. Rice is the only cereal which is usually washed in the course of domestic preparation and this process has a serious effect on its nutrient content.

Husked (whole) rice is less impoverished by washing than home-pounded, undermilled, or milled rice because the grain is protected by the intact seed coat or pericarp. In Table 11 the losses of thiamine, riboflavin, and niacin occurring during the washing of brown (husked) and milled rice respectively are compared; the figures are 21.1 and 43 percent for thiamine, 7.7 and 25.9 percent for riboflavin, and 13.0 and 23.0 for niacin. In experiments on samples of California husked rice, little loss of thiamine was observed after rapid washing (31). The following data on losses due to washing may be given for purposes of illustration. Intensive washing removed approximately 50 percent of thiamine in undermilled and home-pounded rice (Table 13). In another series of experiments (Table 14) as much as 55 percent of thiamine in milled rice was found to be lost. The washing of polished rice in the Japanese way is said to result in a loss of 16 percent of protein, 2 percent of carbohydrates, 43 percent of fat, 73 percent of the inorganic substances, and “100 percent of vitamin” (32). (“Vitamin” presumably means thiamine.) Washing according to Chinese methods also has a depleting effect (33). The actual percentage losses of nutrients during washing reported by different workers vary considerable, largely, no doubt, because the method of washing varied in the different experiments, but the general effect of washing has been clearly demonstrated.

Parboiled rice is less seriously affected by washing than ordinary rice. Rice infested with weevils or molds is usually more impoverished by washing than sound rice, because the damage to the structure of the grain facilitates extraction of nutrients by water, and because such rice needs more intensive washing. It was pointed out by the Baguio Nutrition Committee that rice containing broken grains and particularly screened broken grains tends to be washed more vigorously than good rice, and that nutrients are more readily extracted from broken particles than from intact grains.

Methods of cooking followed in different countries include the following:

- (a) Large amounts of water are used and the excess drained away, carrying with it much starch which has been rendered soluble.
- (b) The rinsed raw rice is immersed in water just sufficient to swell the grains properly and cooked in a double boiler or over a slow fire, to avoid charring at the bottom, until the water is fully absorbed.

- (c) Rinsing of the cooked rice. This is often done to ensure the complete removal of the films of soluble starch on the surface of the grains.
- (d) Rice is sometimes partly cooked by boiling, after which the water is drained off and the half-cooked rice is steamed to a state of tenderness in a pan or basket in an enclosed space over freely boiling water.

While cooking may deplete rice of nutrients, cooking losses are in general less serious than losses due to washing. The method of cooking which causes most depletion is that of using excess water and subsequently discarding the surplus water. It will be seen from Table 14 that as much as 30 percent of the thiamine remaining in washed rice can be removed by cooking in this way. Cooking in open vessels leads to greater losses of thiamine than cooking with a double boiler (15); the same is true of riboflavin and niacin (Table 15).

The combined effects of washing and cooking on nutrient content may be most serious, particularly when "bad" practices are followed in each case. Thus it has been reported that only 15 percent of the thiamine present in milled rice remained after the rice had been washed and cooked by methods in common use in certain parts of India (30). In another investigation in India the following losses of calories and nutrients resulting from similar methods of preparation were observed: calories 15 percent, protein 10 percent, iron 75 percent, calcium and phosphorus 50 percent (34). It has been truly said that the drastic washing of rice combined with the discarding of the cooking water will nullify any improvement in the nutritive value of the rice previous to household preparation. This refers to improvement achievable by any known method. Limited washing and suitable cooking methods, however will very substantially reduce losses (35).

There are numerous combinations and variations of washing and cooking. Only regional studies can determine whether, in any given area, rice is washed and cooked by relatively "nondepleting" methods. In some areas, e.g., in Indonesia, rice is usually steamed instead of being cooked; steaming (if done in the right way) preserves nutrient content more satisfactorily than boiling.

Parboiling

Parboiling is an ancient method of processing paddy which originated in India and is widely followed in that country. In other rice-eating countries the use of parboiled rice is usually confined to Indian immigrants, or descendants of Indian immigrants,² and the rest of the population prefers raw rice. It has been estimated that about one-fifth of the world's rice crop is parboiled. The parboiling of rice has certain nutritional advantages, which have been demonstrated by scientific research during recent decades and are now becoming generally recognized. Reference will be made in a later section to rice "conversion," which is essentially similar to parboiling except that modern technological methods and machinery are applied in the parboiling process.

² Parboiled rice is eaten by Indians far removed from their homeland in British and Dutch Guiana.

The process includes four different stages: soaking, steaming, drying, and pounding or milling.

In the usual procedure, paddy is soaked in water for one or two days, the period depending on the temperature of the water and the quality of the paddy. During soaking, the grain absorbs water. If the temperature of the water is relatively high and soaking is prolonged, some extraction of thiamine may take place. In prolonged soaking the water may have to be changed several times to prevent bacteriological decomposition of the paddy.

The paddy, after soaking, is steamed at atmospheric pressure for a short period—30 minutes or less—in a suitable vessel by the use of perforated steam pipes. In villages, steaming may be effected by heating the paddy in a small container with a limited amount of water. Steaming splits the woody husk, making its subsequent removal easier; this is doubtless one of the reasons underlying the original adoption of the parboiling process. During steaming, thiamine and other water-soluble nutrients, originally concentrated in the germ and aleurone layer, diffuse through the grain. When the germ and aleurone layers are removed by milling, the loss of water-soluble vitamins is therefore much less than the loss which occurs in the milling of raw rice (36). If parboiling is properly performed, and thiamine and other water-soluble nutrients are more or less homogeneously distributed throughout the whole kernel, milling does not greatly diminish the concentration of these constituents in the grain, and the total loss of water-soluble nutrients will be approximately proportional to the percentage of bran and polishings removed.

After steaming, the paddy must be dried. Various drying methods are followed and there is little uniformity or standardization. The grain may be spread on stone or concrete floors and dried in direct tropical sunlight, or it may be dried in the shade in a windy place. If drying takes place too rapidly, the outer parts of the grain may become dry while the interior remains moist, and rice dried in this way may subsequently deteriorate with some rapidity. On the other hand, decomposition may occur if drying is too slow, and the whole of the grain remains moist for too long a period.

Parboiled paddy after being dried is pounded or milled in the same way as raw rice. Parboiling toughens the grain and reduces the percentage of "breakages" during milling. Milled parboiled rice is less easily attacked by weevils than milled raw rice and has somewhat better keeping properties generally. Parboiled rice of good quality has a slightly yellow tint, but if the process is carelessly carried out, e.g., if soaking is prolonged without change of water, the final color may be brownish, and a disagreeable odor may be present. The taste and flavor of milled parboiled rice resemble, to some extent, those of undermilled raw rice. People accustomed to milled raw rice do not usually like parboiled rice and vice versa.

Milled parboiled rice contains two to four times as much thiamine as milled raw rice (37). The same is approximately true of niacin. Illustrative data will be found in Tables 14 and 16. Apart from this advantage, washing affects the water-soluble vitamin content of parboiled rice much less seriously than

it affects that of raw rice. Table 14 gives the results of experiments showing that, whereas raw milled rice lost, in washing and cooking, about 77 percent of the thiamine originally present, the loss from parboiled milled rice, treated in the same way, was only about 36 percent. After washing alone, parboiled milled rice may contain, on the average, four times as much niacin as washed raw milled rice, and the same is approximately true of thiamine (38). The explanation appears to be that the penetration of the water-soluble vitamins into the grain during steaming makes them less "accessible" to the water used in washing.

These facts partly explain why adult beriberi is much less common in populations consuming parboiled rice than in those consuming raw rice. (It is possible that infantile beriberi may occur, perhaps in relatively mild form, among the former; this disease, as has been said, is often unrecognized.) Both epidemiological observations and laboratory research have clearly shown that a poor rice diet based on milled parboiled rice is better than a similar diet based on raw milled rice, in respect of its content of certain important nutrients.

Storage

It is obviously essential that the spoilage of rice by rodents, insects, and molds should be kept down to the minimum. According to one estimate, damage by rodents alone in India accounts for about a million tons of all food grains while a similar amount may be lost as a result of damage caused by insects and moisture (39); rice is the largest of Indian cereal crops. Even in the United States of America, where storage conditions are relatively good, losses in stored grain have been assessed in terms of money at a figure as high as 300 million dollars annually (15). Clearly, therefore, the prevention of spoilage would help substantially in closing the present gap between supplies and requirements. The problem of satisfactory storage has been brought into prominence during recent years since the procurement and rationing programs introduced in various countries as a result of food shortages usually involve the bulk storage of cereals prior to distribution.

Husked and undermilled rice are more liable to attack by insects and molds than are milled rice and paddy. The storage of rice in the form of paddy is thus theoretically preferable. Paddy is bulky, however, and is usually stored as such only on a small scale by families, small producers and merchants. For commercial or bulk storage and transport, milled rice is more economical than paddy because of its smaller bulk. Moreover, paddy is by no means completely immune to weevil and fungus attack. Too favorable an impression of the keeping qualities of paddy may be gained from the fact that in the husking and milling of deteriorated paddy spoiled grains tend to be removed with the husk, and the milled product appears to be relatively free from damage.

Rice with a high moisture content is more liable to be attacked by insects and molds than rice which is comparatively dry. If stored rice is too moist,

ventilation is necessary to prevent "self-heating," which does not occur in dry rice. Deterioration of this kind not only tends to make rice inedible owing to rancidity, moldy taste, and bad appearance, but also leads to losses of nutrients which have been studied in the case of wheat, corn, and rice (15). The prolonged storage of rice under bad conditions affects cooking quality also, probably as a result of changes in the starch fraction.

It has been reported that the thiamine content of rice (paddy, husked, undermilled, and milled) may be reduced by 8 to 15 percent during storage for nine months at a temperature of 84°F. (23). Cold storage for two and one-half years did not cause any significant loss of vitamins in rice, but the average percentage losses in whole kernels kept at room temperature for the same period were 24.9 for thiamine, 5.3 for riboflavin, and 3.9 for niacin. The losses with ground rice were slightly higher (23). The effect of storage on the thiamine content of rice is also illustrated in Table 17. Considerable losses of nutrients may occur in rice during long storage even under good conditions and it is clear that the effects of bad storage conditions will be more serious.

The prevention of spoilage and improvement in the storage of rice are technical problems which cannot be considered in this survey. In a great part of the rice-eating areas in Asia, rice is produced and consumed locally and the producer is often the consumer. In such circumstances paddy or rice is often stored for relatively short periods, and not in large bulk. Methods of storing rice and other grains followed by small producers and merchants in rural areas are based on custom and experience and may be reasonably satisfactory, or at least about as good as can be achieved with existing facilities. They can be improved only by education and propaganda preceded by the study of local conditions and problems. Improvements in methods of bulk storage can be introduced more easily and can be regarded as more important in the present situation of short supply. Progress can be made only by the introduction of modern technical practices. Husked and undermilled rice which is thoroughly dried and kept in properly constructed and ventilated stores will remain undamaged for surprisingly long periods. Before the war, good results were obtained in the Netherlands East Indies by storing husked rice in the presence of lime which does not destroy thiamine to any appreciable extent as long as the mixture is dry.

Considerable experience has been gained during recent years of improved methods of storage, including methods of preventing rancidity and infestation with insects, molds, and rodents. These must be introduced on a wider scale throughout rice-eating areas. Many of the practices which have been found effective in the bulk storage of corn and wheat can be adapted to rice.

V Improvement in the Nutritive Value of Rice as Consumed

Any method of improving the nutritive value of rice must, if it is to be successful, involve little expense and be adapted to local conditions. Lessons can no doubt be learned from the measures taken in certain Western countries to conserve or enhance the nutrient content of wheat flour, but circumstances in these countries and in the rice-eating regions differ so widely that comparisons are often not very helpful. Technical and administrative measures appropriate in Western Europe or North America may not be so in East Asia. Tropical climate, resistance to change in ingrained faulty food habits, the difficulty of improving nutrition by education in poor and underdeveloped countries and of imposing technical and administrative controls in such countries—these and various other environmental, social, and economic factors influence the approach to the problem.

An immediate aim should be the prevention of beriberi. A disease about which so much is known should not be allowed to persist. The Hot Springs Conference declared that the eradication of food deficiency diseases should be the first step in improving nutrition throughout the world.

Milling

The use of home-pounded or undermilled rice in place of highly milled rice has been advocated by nutrition workers and others since the early years of the present century—on the whole with very little effect. Some of the problems involved in discouraging the use of milled rice are discussed below. In the first place, it should be realized that in some rice-eating countries a large proportion of the rice crop is still eaten in the home-pounded state. It was, for example, estimated that in India in 1939 some 70 percent was so consumed, although in certain provinces, e.g., the Madras Presidency, only 30 percent of rice eaters used home-pounded rice because of the spread of rice mills. In Java, with a population of 50 million, only 20 percent of the rice crop reached rice mills during the years 1935-39, and one third of this was only husked in the mills.

The report of the Bandoeng Conference refers to the desirability of checking the spread of mechanical rice mills in rural areas and “conserving the healthy habit of consuming home-pounded rice.” This has been advocated both on nutritional grounds and because home-pounding is a source of rural employment. In practice, however, few governments have attempted to check the spread of rice milling or to reduce the number of existing mills. In normal

times the rice milling industry shows a general trend towards expansion and the use of milled rice increases simultaneously; the reasons for this include preference for the taste of milled rice, the tendency of rural people to adopt urban habits, and the saving of labor. The rice mill can perform in a few minutes a task requiring an hour or more of heavy hand labor.

In certain countries imported rice, which is usually highly milled, is cheaper than locally produced home-pounded rice. In such circumstances the former tends to compete successfully with the latter. It will be difficult to preserve the habit of home-pounding or to control the degree of milling of home-produced rice if imported milled rice is available at a lower price. Systems of price control to protect home-produced rice were introduced in Java and Japan during the prewar years.

The next possibility to be considered is that of encouraging or enforcing the use of undermilled rice, i.e., rice which is processed in mills but retains a proportion of the parts of the grain which are richest in essential nutrients. The same difficulties with regard to taste, appearance and acceptability arise as with home-pounded rice. Further, both undermilled and home-pounded rice have poorer keeping qualities than milled rice. This may not be an important point when the rice crop is consumed soon after harvesting and storage is not prolonged. With improvement in storage conditions the disadvantages of undermilled rice in respect of keeping qualities can be at least partially eliminated. The storage of husked or undermilled rice for many months and its long-distance transportation might be difficult, but modern technology, including the application of insecticides and chemical substances to prevent infestation, moldiness, and rancidity, could do much to make this feasible.

Regulations prohibiting the milling of rice beyond a certain degree have been introduced during recent years in Java and India; in the latter country their purpose was to increase total supplies of rice rather than to increase nutrient content (40, 41). During the war, rice millers in the United States of America adopted a favorable attitude to undermilled rice because its yield is larger than that of milled rice, and also because consumers were less meticulous in their preferences during the war period. It has been estimated that in the United States the yield of head rice from a barrel of paddy (162 lbs.) is increased by 8 to 10 lbs. if the rice is undermilled; the usual yield of highly milled rice is about 87 lbs. (15).

Governmental regulation of the degree of rice milling involves the definition of the product required. In the case of wheat, suitable extraction rates can be laid down and enforced and correlated fairly accurately with the nutrient content of the resulting flour. Rice presents more difficulties. It would be convenient if a suitable extraction rate of, let us say, 70 percent for rice could be chosen and related to a definite figure for thiamine content. Extraction rates for rice are, however, not clear-cut. Rice milling is in general not a standardized process like wheat milling and there are various kinds of rice mills. In small mills husk and bran are often removed simultaneously so that

the weight of the mixture separated from the grain is not a true index of the extraction rate in the usual sense of the term. Another reason why weight loss is not a sensitive index of degree of milling is that the thickness of the aleurone layer differs in different varieties of rice. A further complication is the existence of long and short varieties of rice which are differently affected by the milling process. For these reasons, nutrient content does not run parallel with extraction rates.

Simple inspection of the end product indicates the degree of milling to the experienced eye, and can give a rough idea of nutrient content. Inspection can be made easier by the use of coloring agents or dye-stuffs (e.g., iodine or Lugol's solution) which stain the starchy endosperm, showing how much of the pericarp and aleurone layer remains.¹ The stained rice can be compared against colored diagrams. Among the disadvantages of inspection are that it is subjective and that it is difficult to include methods based on inspection in government orders. Much attention has been given in the past to the development of such methods, but this line of approach can now be regarded as obsolete.

The best method is the direct determination of nutrients in the milled product. The old " P_2O_5 method" is unsatisfactory because phosphorus content does not provide an accurate indication of thiamine content and phosphorus itself is not a very important nutrient in the sense that there is no evidence that it is lacking in typical rice diets. The best indicator is thiamine content.

Numerous methods for the estimation of thiamine, many of which are elaborate and time-consuming, have been devised. The simplest and least time-consuming are those which depend on the oxidation of thiamine to thiochrome or its coupling with diazo compounds. These have been modified in various ways because of the numerous difficulties met with in different laboratories; often methods which seem to produce satisfactory results in one laboratory give rise to trouble in others. Mention may also be made of fluorometric methods (23, 43, 44, 45, 46) which seem to be promising, a new colorimetric method (47), and the color reaction devised by Lemon (48). A collaborative study was made in 1946 to compare various features of published methods of thiochrome estimation (49).

The Baguio Nutrition Committee was of the opinion that "a thiamine content of 1.8 micrograms per gram for all milled rice as purchased should be the ultimate goal. The thiamine content of rice is itself highly important because lack of thiamine causes beriberi, and it can also serve as a convenient index of the degree of retention of other nutrients. In selecting this level, allowance is made for subsequent losses taking place during household preparation, i.e., it is sufficiently high to ensure that the rice as finally consumed will not be dangerously poor in thiamine." The Committee pointed out, however, that "the production of rice which retains 1.8 micrograms per gram of this vitamin raises a number of difficult problems. In the first place, rice which is under-

¹ Mention may also be made of the method suggested by Goudswaard (42), in which indigo-carmin and fuchsin in alcoholic solution are used.

milled to this degree will not keep as well as highly milled rice in the poor storage conditions at present generally found in rice-producing countries. The keeping qualities of such rice can, however, be greatly improved if its moisture content is kept low and other conditions of storage are satisfactory. Secondly, undermilled rice is in general less acceptable to the consumer than highly milled rice." In the circumstances, it was recommended that "a content of 1.5 micrograms of thiamine per gram of milled rice be at present accepted as a minimum, with the proviso that when improved milling or processing of rice permits, the higher level be adopted."

The acceptability of undermilled rice is of crucial importance. In some rice-eating countries, e.g., the Philippines, the preference of consumers for white highly milled rice appears to be particularly strong, while in parts of South China undermilled rice is more generally accepted. An analysis of the economic, social, and psychological factors influencing the use and acceptance of home-pounded and undermilled rice will be found in "The Rice Problem in India" (30). It is to the advantage of the rice miller to mill rice as lightly as the market will accept it, since the lighter the milling the greater the yield of finished rice per unit of husked rice and the smaller the percentage of breakages.

The Baguio Nutrition Committee laid stress on "the possibility of milling rice in such a way that the portions of the grain richest in vitamins are retained in the milled product, while at the same time the latter is acceptable to the consumer in respect of appearance and flavor." The design of rice mills and rice milling practices are generally speaking crude and old-fashioned; little attention has been given to their modernization and improvement. The problem referred to by the Committee requires collaborative investigation by engineers and nutrition workers.

Brief reference may be made to yet another aspect of the subject. More calories and nutrients for the human consumer can be obtained from a given quantity of whole rice when the rice is undermilled than when it is highly milled. On the other hand, the quantity of rice polishings available for the feeding of livestock is reduced. Hence the wider use of undermilled rice would call for an increased production of fodder.

Washing and Cooking

Reference has already been made to nutrient losses caused by washing and cooking, and to the advantage of parboiled rice in this respect. Laboratory research on the effect of washing on raw rice has been confirmed by the following interesting human experiment (10):

"One group of workers was fed on rice, freshly and highly milled each day and cooked, by the method described above, without preliminary washing. Control groups were observed, fed on rice milled to a similar degree but washed thoroughly in the ordinary way. Side dishes and other conditions were comparable in all the groups. No signs of beriberi developed in

the group on the unwashed rice, whereas, in the control groups nearly half the subjects developed signs attributable to vitamin B₁ deficiency. The rice used in this experiment was actually stored in bags, in the husk, as no facilities were available for storage in airtight containers; but the evidence presented above suggests that this would have been a more satisfactory way of conserving the vitamin B₁. It may then be claimed, on the grounds of these results and on the basis of what we now know of the requirements of vitamin B₁ and of its behaviour in rice under storage, processing and cooking, that—under properly controlled conditions—it is possible to feed highly milled rice without special provision of foodstuffs rich in vitamin B₁ in the diet, and yet avoid the development of beriberi even in its earliest clinically recognisable forms.”

A single vigorous washing of the rice, during which the vessel containing the rice is shaken, and the rice stirred or rubbed with the fingers, removes a considerable proportion of the water-soluble nutrients originally present. Subsequent washings have less effect, so that there is not much to be gained by reducing the number of washings. Rice containing dirt and other impurities must be washed, and the only procedure that can be recommended is to steep the rice in no great excess of water and avoid shaking, stirring, or rubbing. If rice as it reaches the household were free from impurities, washing might be unnecessary or could at least be reduced to a minimum. To make such rice generally available, a sanitary reformation in methods of handling rice from the field to the kitchen, and, in particular, greater cleanliness in mills, godowns, retail shops, and markets, would be required. Rice which is moldy and infested by weevils will naturally be washed more intensively than sound rice. There is a direct and important link here between improvement in storage and marketing conditions and nutrition.

Improvements in methods of washing and cooking can be introduced without much difficulty into institutions, such as hospitals and prisons. Their introduction into households is another matter. People are usually reluctant to change time-honored household cooking practices and a sustained educational effort would be required to induce them to do so.

The views of the Baguio Nutrition Committee on the washing and cooking of rice were substantially the same as those expressed in this survey. With regard to education in improved household practices, the Committee commented that “any educational campaign must be related to the customs of the country or area concerned, and be based on full knowledge of existing methods of household preparation.”

Parboiling and "Conversion"

The parboiling of rice has been discussed in Chapter IV. Parboiled rice can be milled to a high degree without serious loss of thiamine and other water-soluble nutrients and is depleted of vitamins on washing to a smaller extent than raw rice. Experience shows that rice eaters tend to prefer milled rice to

undermilled or home-pounded rice. The process of parboiling places at their disposal a kind of rice which can be highly milled and at the same time possesses most of the nutritive properties of undermilled rice. In practice, however, the substitution of raw rice by parboiled rice presents serious difficulties. Parboiling is not a standardized process and the quality of the end product is very variable. Milled parboiled rice is usually less attractive in appearance than raw rice milled to a high degree of whiteness, and it has a different taste. The latter has often a certain "social prestige" which parboiled rice has not.

Some of these disadvantages might be removed by the introduction of the product known as "converted" rice. Rice "conversion" (and also the similar process known as "Malekising") is essentially parboiling technically perfected, modernized, and protected by patents. In the "conversion" process, paddy is placed in a vessel and washed. The water used for washing is removed and hot water (75° to 85°C) is then introduced under pressure, and the paddy is steeped for a period of 120 to 165 minutes. As in the case of ordinary parboiling, the duration of steeping depends on variety, moisture content, and the period during which the paddy has been stored. In general, however, the soaking process is more carefully standardized than in ordinary parboiling.

After being soaked the paddy is heated by dried steam in cylindrical rotating vessels for a few minutes only. It is then dried *in vacuo* in a rotating, steam-jacketed vessel until its moisture content is under 15 percent. The final drying takes place at atmospheric pressure. It is also possible to carry out the whole drying process at atmospheric pressure at a temperature of 145° C or under (15). The hot dry "converted" paddy is cooled by passing air through it and keeping it in bins for at least eight hours before milling. This tempering period is necessary to produce a state of "moisture equilibrium" throughout the grain before milling.

Rice "conversion" (and also "Malekising," about which not much information is available) can produce an attractive highly milled product with the nutritive properties of parboiled rice. The percentage of breakages during milling is considerably lower than in the case of raw rice (Table 18). The yield of finished rice is greater and the tough "converted" grain is more resistant than raw rice to insect and bacteriological infestation. "Conversion," however, is more expensive than ordinary parboiling because relatively complicated machinery is needed and the process is covered by patents.

The Baguio Nutrition Committee considered "converted" rice an acceptable product. It felt, however, that since the plant required for "conversion" is elaborate and expensive the most satisfactory way of encouraging the use of parboiled rice is likely to be the modification and improvement of simple parboiling methods in current use.

The replacement of milled raw rice by parboiled or "converted" rice raises a number of problems which require study and analysis. There is, for example, little information about the relative digestibility of these kinds of rice. Recently the parboiling process has been given some attention by nutrition research workers. The effect of soaking paddy in minimum quantities of water at

varying temperatures for a short time and of drying at ordinary pressure in an inexpensive drying apparatus is being studied. An interesting investigation on the parboiling of rice by simple standardized methods on a laboratory scale has already been reported (50). This concerned the effects of the following: boiling; boiling and steaming; steaming; soaking, boiling, and steaming. Data were obtained about the influence of various modifications in procedure on thiamine content and the percentage of breakages.

It may be possible, by suitable modification and adjustment of the various stages in parboiling, to produce cheaply a milled product whose appearance and taste would be acceptable to rice eaters in general.

The Nutrition Advisory Committee of the Indian Research Fund Association in the report of its 14th meeting (1946), commented as follows:

“Further work should be undertaken on the rice problem, and standard conditions for parboiling with known varieties of paddy worked out. On the basis of this work, recommendations should be made to the Government to design small units of parboiling plants suitable for use in villages.”

The Baguio Nutrition Committee recommended that “improved methods of parboiling should be investigated with the aim of producing cheaply rice which has the valuable nutritive properties characteristic of parboiled rice, but which at the same time is acceptable in rice-eating countries in general. Consumer trials with such rice should be carried out in different countries and the results made available by FAO to other rice-eating countries.”

Rice Enrichment

The policy of enriching wheat flour of low extraction with certain nutrients, successfully adopted in the United States of America, has focused attention on the possibility of a parallel procedure in the case of rice. The prevalence of beriberi and other vitamin deficiency diseases in rice-eating areas indicates the need for a greater intake of certain vitamins. It is clear, however that the enrichment of rice is technically more difficult than the enrichment of white wheat flour. Synthetic vitamins can be mixed homogeneously into a flour, but rice is eaten in the form of uncrushed grains. Moreover, rice unlike wheat, is usually washed before being cooked.

Methods of solving at least some of the technical problems involved in rice enrichment have been devised. The data about rice enrichment given below are taken from a report of Kik and Williams (15) which is the best available source of information on the subject.

The aim of rice enrichment is to add nutrients to milled rice so as to give the resulting product a nutrient content which is considered desirable on public health grounds, for example, a nutrient content equivalent to that of husked rice. Two methods of enrichment have been reported. In both, enrichment involves two steps: (a) preparing a fortified *premix* and (b) diluting the premix with ordinary white milled rice in a subsequent process.

The first method was worked out in the laboratories of Messrs. Hoffmann-LaRoche (51). The premix consists of ordinary white milled rice which is

impregnated with a concentrated solution of the vitamins and/or minerals chosen for enrichment. The impregnated grains are then coated with film-forming edible substances. This coat protects the vitamins against deterioration and prevents substantial losses during the washing prior to cooking.

The final enriched product is prepared by blending the premix with rice by means of a suitable mixing procedure. Neither the premix nor the converted rice differs in appearance from ordinary white rice, if thiamine, niacin, and iron in the form of pyrophosphate are the nutrients added to the premix. The addition of riboflavin, which has a strong yellow color, changes the color of the premix sufficiently to make the impregnated grains visible in the blend.

Fortification of the premix with 1 mg. of thiamine and 13 mg. of niacin per gram, and the blending of the premix with milled rice in the proportion of 1 to 200, yield a final product with a vitamin content equivalent to, or somewhat higher than, that of husked rice. Enriched rice so prepared contains 5 micrograms of thiamine and 65 micrograms of niacin per gram. The cost of these vitamins, the coating ingredients, the manufacture of the premix, and the blending of the premix with white rice is estimated not to exceed .25 cent per kilogram of enriched rice (equivalent to an increase of 1.7 percent in the cost of rice, calculated on the basis of a wholesale price of 15 cents per kilogram).

Tests have shown that by the use of the advocated mixing method the premix is homogeneously distributed throughout the finished enriched rice. Flavor and cooking quality are not affected by the enrichment procedure. It is claimed that the household washing of enriched rice prior to cooking will not remove more than 3 to 5 percent of the added vitamins. Storage of the premix rice for one year at room temperature in the United States of America did not result in loss of the thiamine and niacin added. After storage for three weeks at 45° C, a loss of only 3 percent of thiamine and no loss of niacin were observed.

In the second method of artificial enrichment, developed by E. A. Fieger, white rice grains are impregnated with a solution of vitamins in water (thiamine, niacin, and highly soluble salt, primary sodium phosphate). The rice is dried and coated with a thin collodion membrane. This protects the vitamins from extraction during washing, but when the rice is cooking the vitamins diffuse into the cooking water, since the film is removed by hot water. The enriched rice is prepared in a concentrated solution of vitamins, and subsequently diluted with unenriched white rice in the proportion of 1:100.

The losses of vitamins occurring during the cooking of both kinds of enriched rice are shown in Table 19. The rice prepared by the Hoffmann-La Roche method showed smaller loss.

The following considerations in support of enrichment are put forward by Kik and Williams (15):

"One might consider 1 milligram thiamine per day per capita a reasonable minimum provision . . . if the utmost economy were necessary. This would correspond roughly to 1 milligram per pound of rice where the rice consumption is high (365 pounds per capita). At the present price in the

United States, the cost of thiamine for such fortification would be less than 1.6 cents per 100 pounds of rice, or 5.84 cents per capita per annum. Of the Hoffmann-LaRoche cost figure of 0.114 cent per pound, quoted above, about half represents the cost of the vitamins; the remainder covers coating ingredients, premix preparation, etc. For the Orient, these accessory costs must be reduced to a minimum. In the enrichment of flour in the United States (a simpler process) accessory costs amount to 40 to 50 percent of the basic ingredient costs. It would seem that eradication of beriberi in the Orient by the use of synthetic thiamine will, at best, cost 10 cents per capita per annum. This, however, would be a small price to pay for the benefit to be gained.

“An economic advantage of such artificial enrichment over any form of parboiling is that only 1 to 2 percent of the rice requires special processing. Where weather conditions permit prompt and satisfactory sun drying of parboiled rice, this should not be costly. However, when artificial drying must be resorted to, either constantly or intermittently with changes of weather, drying costs may equal or exceed the cost of fortifying ingredients. On the other hand, if parboiling saves a large amount of breakage and if under Oriental conditions such breakage results in serious loss of salability, the advantages may lie with parboiling. The perils of inadequate or improper drying under tropical conditions also need careful evaluation.”

The importance of eradicating beriberi has been emphasized throughout this survey. It seems highly probable that the introduction of enriched rice would be an effective means of preventing this disease in certain areas in which it is highly prevalent, and particularly in urban areas. Careful attention should be given by public health authorities and others to the possibility of using this new weapon in the campaign against beriberi.

Enrichment has, however, certain disadvantages when considered as a means of improving the nutrition of rice eaters on a wide scale. A number of practical problems would have to be solved in arranging for the preparation and distribution of enriched rice. The blending of the premix with the milled rice must take place either at the mill or in depots where rice is stored, and the process must be inspected and effectively controlled. This may be feasible where there are large mills and the rice industry is well organized generally, but where rice mills are many and small, and rice dealers and stores are numerous, the introduction of enrichment will present formidable difficulties. These will be accentuated in rural areas where mills are scattered. In the very considerable areas where home-pounded rice is still generally eaten and the producer usually consumes his own rice, enrichment would be impossible, but since home-pounded rice is not impoverished of vitamins to the same extent as milled rice it would be less necessary. The small producer may, however, take his rice to a local mill and have it milled for consumption by himself and his family. A considerable organizational effort would be needed to ensure that rice was enriched under such circumstances.

In the enrichment procedure at its present stage of development only thiamine, niacin, and iron are added. The addition of riboflavin gives the premix a strong yellow color which remains visible after blending and cooking. A grain mixture containing strongly colored grains in the proportion of 1:200 might be even less appealing to the purchaser and consumer than undermilled or parboiled rice. Riboflavin deficiency is, however, common in rice-eating areas. Apart from riboflavin, typical rice diets have other defects which will not be corrected by the use of enriched rice as at present prepared. These include deficiency of other vitamins in the B₂ group. With regard to the enrichment of wheat flour it has been remarked that "there is good reason to think that where measurable factors of the vitamins of B₂ complex are deficient other factors which are not measurable and some which remain unknown, will be deficient too. Since some at least are known to be important for health, a policy of enrichment of white flour with only the B₂ group of vitamins must be regarded as unsatisfactory" (52).

Recent research has shown that deficiency of pantothenic acid is concerned in the causation of the "burning-feet" syndrome, (53) and further investigation may indicate the importance of lack of other vitamins in the B₂ complex in rice-eating areas. Again, calcium deficiency is among the most important defects of typical rice diets and enrichment according to existing procedures does not make good this deficiency.

The greater part of the "poor rice diet" consists of rice; the rest of the diet is not usually rich in foods of high nutritive value. While rice of any kind is a poor source of riboflavin, it is probable that a rice diet based on home-pounded, undermilled, or parboiled milled rice is superior, at least in certain respects, to a similar diet based on enriched rice. Further investigation of this subject is needed. There is some evidence that the intake of relatively large amounts of certain food factors may accentuate deficiencies of others. Thus, it was observed in Japanese prison camps after the war that the treatment of pellagra with large doses of niacin tended to precipitate the appearance of beriberi. It seems unlikely that enrichment as described above would involve dangers of this nature, but the possibility should be borne in mind.

Finally, it should be pointed out that synthetic vitamins are not at present manufactured in the rice-eating countries of the world. There is no essential reason why they should not be, though manufacture might be difficult in certain countries at their present stage of technical development. Meanwhile, however, they must be obtained from abroad. During the recent war supplies of cod liver oil and vitamin A concentrates to East Asian countries were reduced or cut off both because of shortage of total world supplies and because of transport difficulties. To expect the recurrence of such interruptions to international trade would be pessimistic. It is, however, worth noting that, as things are, the adoption of a policy of rice enrichment in the rice-eating regions involves dependence on supplies of vitamins from distant parts of the world.

The Baguio Nutrition Committee expressed the view that rice enrichment is

likely to prove particularly useful in areas in which beriberi is an important public health problem, but that it should in general be regarded as an expedient which does not remove the need for the improvement of rice diets in other ways. It stressed the fact that enriched rice as now prepared does not provide additional amounts of nutrients much needed by rice eaters. It hoped that the results of any field experiments with enriched rice would be carefully recorded for the benefit of all rice-eating countries.

Such an experiment is now being organized in the Bataan province in the Philippines. It has been estimated that in this province some 80,000 cases of beriberi occur annually and that in certain districts 7 to 9 percent of the population may be affected. The disease is more common in villages in the province than in towns.

VI *Rice Diets*

General

In the previous chapter the nutritional improvement of rice itself has been discussed. The rice eater's diet as a whole will now be considered. It has already been pointed out that, whatever the kind of rice eaten, rice diets are in general ill-balanced and defective according to modern nutritional principles, because they contain too much cereal and too little of other foods such as milk and milk products, meats, fish, eggs, vegetables, and fruits. Examples of such diets are shown in Tables 2 and 20, Table 20 being based on data presented in the *FAO World Food Survey* (1946).

The deficiencies of rice diets in terms of nutrients were described by the Baguio Nutrition Committee as follows:

"Insufficiency of the B group of vitamins is probably the most important fault of typical rice diets. Emphasis must also be laid on deficiency of vitamin A and calcium. While there is no clinical or physiological evidence that rice diets of adequate calorie value are deficient in protein, a greater intake of protein by the rice eater, and the inclusion in his diet of protein derived from foods other than rice in greater quantities, would be advantageous. This is unquestionably true as regards growing children. No satisfactory data are available about the quantities of fat needed by human beings. Fat intake in rice-eating countries is, however, considerably lower than intake in Western countries in general, and it is well known that rice eaters do increase their fat consumption when circumstances permit. Fat facilitates the absorption of certain vitamins and 'spares' thiamine. In view of these facts an increased intake of fat is desirable."

Considerable attention has been given during recent years to the problem of improving rice diets. Useful contributions will be found in the national reports prepared for the League of Nations Inter-governmental Conference of Far Eastern countries on Rural Hygiene held in Bandoeng in 1937, in the Final Report of the Conference, and in a series of papers presented to the South Pacific Science Congress in San Francisco in 1939. "The Rice Problem in India" (30), "The Improvement of the Poor Rice-Eater's Diet" (54), and various reports of the Nutrition Advisory Committee of the Indian Research Fund Association, as well as other publications, have dealt with the problem as it presents itself in India. Various government agencies worked in co-operation to prepare a report, published in the Netherlands East Indies in 1940 (55), in which existing and future nutritional problems in Java, including the rice problem, were analyzed. Workers in China, the

Philippines and various other countries have also made valuable contributions to the subject.

The areas of the world in which rice is the staple food are extensive. Rice eaters include many different racial groups, and conditions vary considerably from region to region. It is, however, generally true that, in comparison with the wheat-eating countries of the West, rice-eating countries are technologically underdeveloped, their peoples are for the most part poor and ignorant, and pressure of population on land available for cultivation is high. Rice-eating countries are at present short both of rice and of other foods. The shortage of rice has been accentuated by the war, but the existing situation is by no means due wholly to the effects of the war and its aftermath. In certain countries the growth of population is outstripping the supply of food that can be produced at existing levels of agricultural development.

In order to improve rice diets generally, the total production of rice and the yield of rice per unit of cultivated land must be increased. This may sound paradoxical, since, as has already been pointed out, typical rice diets contain too high a proportion of rice. A considerable percentage of rice eaters are, however, short of calories, and an increase in the production of rice is perhaps the most feasible method of increasing supplies of calories at the present time. Moreover, greater yields of rice per unit of area are necessary in order to release land for the production of other foods which the rice eater needs.

There is a general impression that agricultural yields are very low in countries in East Asia and that they could readily and rapidly be raised by the introduction of modern agricultural techniques. Data from the *World Food Survey* (57) indicate, however, that production of food per unit of cultivated land in rice-eating countries is relatively large. In North America an average of 2,500 "original"¹ calories are produced per acre; in South America, 4,700; and in Western Europe, 7,500. The corresponding estimate for East Asia is 5,500 "original" calories per acre. On the other hand, the amount of land under cultivation per head of population in rice-eating areas is relatively small; in East Asia it averages about 0.5 acres per caput. In general, the quantity of food produced per head of population is small because the population is dense rather than because yields are poor. The numerous problems involved in raising yields—increasing supplies of fertilizers which are sufficiently cheap to be used by poor cultivators, the introduction of improved seeds and better farm implements, the development of irrigation, and

¹ The calories yielded by crops. On the average, about seven "original" calories are required to produce one calorie from animal products. To put it in another way: if vegetable crops suitable for human consumption are fed to animals, the number of calories from animal sources thereby made available may be about one seventh of the number of calories which could be supplied by the original crops if directly consumed. The relation will, of course, vary from one class of livestock to another, and from one country to another in accordance with differences in the type and quality of livestock and in feeding practices.

so on—will be the concern of the International Rice Council which will soon be established by FAO.

Economic levels are low in rice-eating countries and families which purchase their food must spend a high proportion of the family income—often 70 percent or more—in obtaining their present meager and ill-balanced diet. Until their economic condition is improved, such families cannot afford to buy supplementary foods in sufficient quantity, even when such foods are available. It has been observed that in rice-eating countries, as in other parts of the world, the diets of families in the higher income groups contain a higher percentage of such foods as milk, meat, and fruit than do those of poorer families. The prosperous classes constitute, however, only a tiny portion of the total population in such countries. Another way in which poverty influences diet is that it often forces small producers to sell more expensive “protective” foods of which they are themselves in need in order to be able to buy rice and meet other essential expenditures.

Partial Replacement of Rice by Other Cereals or by Roots

Cereals

Since supplies of rice are short, the question of replacing rice by other staple foods is of immediate importance; it is also an important aspect of the long-range problem of improving rice diets. How far are policies aiming at the substitution of rice by such foods as wheat, corn or millet, justifiable or feasible on nutritional and other grounds? In Chapter III the nutritive value of rice and other cereals was compared. It was pointed out that husked rice resembles in its nutrient content other staple cereals in a similar state. Corn contains a little more protein and fat than rice, and yellow varieties contain provitamin A or carotene; a high consumption of corn is, however, sometimes associated with the disease pellagra, for reasons which are not yet fully understood, though much attention is now being given to this problem. The millets as a group are somewhat richer in protein than rice but otherwise do not differ greatly in nutrient value; the digestibility of millets requires further investigation. On the other hand, rice stands high among cereals in respect of the biological value of its proteins.

The partial replacement of milled rice by another cereal which has not been deprived of its outer layers to the same extent is nutritionally advantageous; it will increase the intake of certain minerals and vitamins, notably thiamine, and hence help to prevent beriberi. This will apply to wheat flour of high extraction, whole or undermilled corn, or the millets which are commonly consumed “whole” or nearly so. Approximately the same result will be attained, however, by the use of undermilled, parboiled, or enriched rice. The use of low extraction wheat flour in place of milled rice cannot be recommended on nutritional grounds since both foods are poor in minerals and vitamins. The excessive consumption of low extraction

wheat flour has been known to cause beriberi, e.g., in Newfoundland.

In the greater part of the rice-eating regions of the world, the cultivation of other cereals in place of rice does not appear to be feasible, at least to any great extent. Rice is the cereal which thrives best in these regions and which gives the highest yield of calories and proteins per acre. The introduction of other cereals into areas in which rice is normally the only cereal produced and consumed presents considerable difficulties. Alternative cereals are unfamiliar and usually disliked, the rice eater does not know how to prepare and cook them, more fuel and different household utensils are often needed for their preparation, grinding stones may not be available for the grinding of wheat into flour—these and many other obstacles are likely to be encountered. A point worth mentioning is that it is difficult for poor people who usually cook only one meal a day to include two different cereals in their diet simultaneously. Considerable experience of these problems has been gained in recent years as a result of rice shortages which made it necessary to import wheat and, in some instances, millet into rice-eating areas to prevent famine. Some success in the replacement of rice by wheat has been achieved in certain countries during and after the war, e.g., in Ceylon, Malay, and some parts of India. Considerable educational effort is needed, however, to overcome prejudices and to influence time-honored household customs and eating habits. The habitual rice eater naturally prefers rice and will eat rice rather than other cereals when it is available.

There are, however, areas in which for climatic and geographical reasons yields of rice are relatively low and both rice and other cereals such as wheat and millets are cultivated. The people in such areas often habitually consume more than one cereal; for example, they may eat rice at one season and wheat or millets at another, or they may change from one cereal to another from time to time in accordance with their relative cost. In these circumstances it may be less difficult to increase production and consumption of cereals other than rice, particularly wheat, both because agricultural conditions are more suitable and because the food habits of the people are more flexible.

Conditions in the various rice-eating countries and areas must therefore determine policy with regard to the substitution of rice by alternative cereals. It is said that in many parts of China there has been a tendency to expand rice production excessively so that lands more suitable for the production of corn, soya bean, and vegetables are being less effectively used for rice production (56). In the Philippines it is believed by many that it would be wise to decrease the production of rice in that country and to grow more corn and other foods. The following statement from a report prepared by the Philippine delegation for the Nutrition Committee in Baguio may be quoted:

“We do not subscribe to the common belief that peoples who are used to living on a rice diet would rather starve than take to other carbohydrate

foods. We rather accept as common to all men the tendency to respond to well-balanced food provided the change is not sudden and that they are allowed to adjust themselves to the new diet. We are supported by the experience of Philipinos who have easily adapted themselves to European and American culinary habits."

Roots

Certain roots, e.g., cassava and sweet potato, flourish in tropical and sub-tropical areas and give high yields. The superiority of such roots to rice, in respect of yield, is not so great as might appear from their yields on a fresh-weight basis, because the harvested roots have a higher moisture content than rice. Rice usually has a moisture content of about 12 percent whereas that of cassava, as harvested, averages about 60 percent. The following figures illustrate the relation between the calorie yields of rice, cassava, and sweet potato by unit of area.

	<i>Rice Milled</i>	<i>Sweet Potato</i>	<i>Cassava</i>
Estimated average yield (metric tons)			
per acre	0.37	1.86	1.86
per hectare	0.914	4.596	4.596
Waste allowance (percent)	—	19	20
Protein yield (kilograms)	28	27	18
Carbohydrate yield (kilograms)	294	413	540
Calories (in thousands)			
per acre	1,325	1,825	2,253
per hectare	3,274	4,509	5,567

Estimated average yields relate to India and are taken from the Final Report of the Famine Inquiry Commission (40).

Starchy roots are poor in protein and devoid of fat. Usually only about 50 percent of the crude protein as estimated by N content is true protein, and little is known about the remaining nitrogenous substances; the true protein is, however, protein of good quality. A comparison may be illuminating here. About 2,400 calories and 56 grams of protein may be supplied by 700 grams of rice; a similar quantity of dried cassava (between 1,700 and 2,100 grams fresh weight) will yield about the same number of calories but only 20 to 40 grams of protein or even less.

The protein content of varieties of certain species of roots and tubers differs considerably, and it is possible, by selective methods, to develop varieties with protein contents above the average. It appears, however, that when such varieties are transferred to poor soil their protein content tends to decrease. Moreover, an increase in crude protein as estimated by N content may represent an increase in nitrogenous substances of uncertain nutritional value, rather than an increase in true protein.

On a dry-weight basis, cassava has approximately the same thiamine content as milled rice, but is richer in riboflavin; sweet potatoes and taro, on the same basis, contain more of these vitamins than milled rice. Irish and sweet potatoes are good sources of ascorbic acid, retaining fair quantities of this vitamin after cooking, and some varieties of sweet potatoes are rich in carotene.

Among the disadvantages of certain tropical and subtropical roots are the following. Fast-growing roots such as cassava tend to deplete the soil with some rapidity and as a result yields decrease after some time. Some varieties of cassava and yams contain toxic substances which may cause poisoning in human beings. These substances are usually washed out during preparation and the occurrence of poisoning is relatively rare, but the washing depletes the roots of nutrients.

The encouragement of cassava and other roots is justified in periods of food shortage; in fact the production of cassava on a large scale has prevented starvation in some parts of the East during recent years. But once cassava has been introduced and has become popular it tends to establish itself firmly in the agricultural economy and dietary regime of the population, and to replace rice to an ever-increasing extent. This will be detrimental in the long run, unless greater supplies of protein-rich foods become available. The greater the consumption of roots and tubers, the more important it is that the diet should contain a sufficiency of foods rich in protein such as pulses, and animal products, notably fish.

Much of what has been said about roots applies to bananas and plantains. These also give a high yield of calories per unit of cultivated land and have a very low protein content. Consumed in relatively small quantities, they are of value as supplementary foods, but they should not be regarded as staple foods and as substitutes for cereals.

Animal Products

A larger consumption of foods of animal origin such as milk, meat, eggs, and fish would greatly improve the nutrition of rice-eaters. The value of milk as a supplement to poor rice diets has been convincingly demonstrated by human experiments. The nutritional targets given in the *World Food Survey* (57) for Southeast and Eastern Asia and other rice-eating regions call for considerable increases in supplies of animal products.

Milk and milk products, meat, and eggs may perhaps be considered as a group since the basic problems to be solved in increasing supplies of these foods are essentially similar. Increased consumption could be brought about by greater local production, by imports, or by both.

With regard to local production, rice-eating areas are generally areas of dense population, and the available land must at present be devoted almost entirely to the production of high-yielding crops, notably rice, in order to provide sufficient calories to prevent hunger. The diversion to fodder crops of land now producing human food or the feeding to animals of vegetable foods suitable for human consumption would mean a reduction in the calories available for human beings. Seven calories of vegetable products are needed on the average to produce one calorie of animal food. Another important point is that large areas in the tropics seem to be unsuitable for maintaining certain kinds of livestock. It is well known that cattle do not thrive in some low-lying tropical rice-growing areas. It is possible, of

course, that milk- and meat-producing animals could be made to thrive on such areas by the introduction of scientific animal husbandry including better feeding.

For these and a number of other reasons, the peoples of the rice-eating areas cannot easily produce more milk, meat, and eggs themselves for their own consumption. The remaining possibility is the importation of these foods from elsewhere. In normal times the agricultural economy of many rice-eating areas is one of self-sufficiency at a low nutritional level. The consumer is often the producer not only of rice but also of the other foods he requires. It was found that in one of the most prosperous regions of Java, only 12 percent of all the foods consumed came from outside the region. The present economy of rice-eating regions is such that expensive foods cannot be imported in considerable quantities.

The picture as a whole is quite clear. The average rice cultivator cannot produce sufficient animal products, because this would mean a reduction in the already inadequate supply of calories; he cannot buy animal products because he is too poor. What is true of individuals is also true of countries and regions. The only solution is a general increase in prosperity and a rise in purchasing power, associated with far-reaching developments in agriculture and industry.

Even in present circumstances, however, something can be done to make larger supplies of animal products available. In certain countries there are areas, now waste land, which could be made suitable for grazing by modern scientific methods. Animal husbandry can be improved by scientific research and its application. Improvement in methods of handling milk, including better storage, transport, and marketing facilities, will further the development of dairy industries in suitable areas. Greater use might be made in some regions of dairy goats which can thrive on small rough grazing areas; the goat is, however, a very destructive animal and if allowed to wonder at large may destroy more food than it provides. In some countries, e.g., China, the pig is the most important meat-producing animal and no doubt more meat could be obtained from this source by better management; the pig is a scavenger and a relatively efficient converter of vegetable into animal food, and hence makes smaller demands on restricted agricultural resources than other kinds of livestock. Small domestic animals, such as rabbits fed on herbage and kitchen wastes, could supply not only meat but also manure for gardens and compounds. Ducks are less susceptible to disease under tropical conditions than other poultry and might be successfully reared in large numbers in the many areas in East Asia where there are rivers, waterways, and canals in close proximity to villages and farms.

Such developments, and numerous others, offer possibilities for increasing to some extent the consumption of milk and meat in East Asia. The technical problems involved need careful study on a local basis.

With regard to imports, special attention should be drawn to the possibility of making greater use of imported dried skim milk for distribution to children

through school-feeding programs organized by governments or other bodies. This would be most desirable, even though only a small proportion of children in rice-eating areas could benefit.

Fish—dried, salted, or fermented—is commonly consumed in small quantities by rice eaters. The merits and defects of diets containing a combination of rice and fish were considered in several papers presented at the Sixth Pacific Science Congress in 1939 (32). Fresh fish is a good source of protein of high biological value, some of the B vitamins, fat, and calcium, its nutrient content varying to some extent in accordance with species, size, and methods of preparation. The drying and salting of fish cause serious loss of vitamins but the protein content of fish processed in this way may be 25 to 30 percent or more. In some countries, e.g., Japan, dried fish ground up with the bones to make a kind of fish meal is a common article of diet. Fish so prepared is a rich source of calcium and the same is true of small fish which are consumed in a fresh state with their bones (58).

Raw fish is eaten in some parts of East Asia. This is undesirable for two reasons: first, it may lead to parasitic infection and, secondly, raw fish may contain the enzyme thiaminase which destroys thiamin.

There is great scope for expanding sea and fresh-water fisheries in rice-eating regions. The success achieved by the Japanese during the first three decades of the present century in developing sea fisheries illustrates what can be done in this direction. The consumption of sea fish is, of course, largely confined to coastal areas. The supply of fresh-water fish is, however, almost as great in some countries as that of salt-water fish; not only lakes and rivers but also fish ponds, and paddy fields during the period of inundation, are sources of fresh-water fish. An increased supply of fish in regions remote from fresh- or salt-water habitats involves improvements and developments in transportation and storage which would necessarily increase cost. Canned fish would be too expensive for general consumption in rice-eating areas. The methods of preservation now generally employed are those of salting and drying. In some places dried and salted fish products which are reasonably satisfactory in taste and keeping qualities are prepared by traditional methods; in general, however, fish prepared by such methods is of poor quality and does not keep well.

At present fishing techniques throughout most of the East are primitive and inefficient, and the same applies to methods of preservation. Discussion of the relevant problems would be outside the scope of this report, but the importance of investigating cheaper and better methods of preservation may be emphasized. Drying and salting processes could probably be greatly improved without seriously affecting the cost of the final product. The possibility of preparing fish meal in a form suitable for human consumption and generally acceptable should be explored. One such preparation is the "nuoc mam" of Siam and Indo-China. It is a sauce, consisting entirely of amino acids and sea salt, which is eaten in small quantities as a flavoring agent. A similar preparation, called "Hsia-Yu," is made in South China.

The South East Asia Fisheries Conference (Singapore, 1947) considered the problem of supplying 650 million people with sufficient quantities of fish. In many countries in East Asia existing supplies of fish are scarcely sufficient to provide 28 grams of fish daily per head of population, and in some regions much less than this amount is available. The Conference agreed that the target to be aimed at was the provision of 100 grams of fish per person per day, which means a total catch of nearly 100 million pounds (45,360 metric tons) of fish per annum. At the FAO series of meetings in Baguio in February-March 1948, an interesting discussion took place between nutrition workers and fisheries experts attending these meetings. The nutrition group emphasized the great importance of increasing supplies of fish in East Asia, because of the fundamental difficulty of increasing those of other animal products, and asked the fisheries experts for their views on the potentialities for greater production in the region. The reply was that no real information on this point is at present available, nor will be until fundamental biological surveys have been made. One of the purposes of the Indo-Pacific Fisheries Council, shortly to be established, is to encourage and organize such surveys.

It is quite clear, however, that fisheries are in general grossly underdeveloped; this applies to fresh-water fishing, inshore fishing and offshore fishing. Striking advances have been made in other parts of the world by the application of modern science and technology in the fishing industry, and no doubt similar progress is possible in the tropics and the East.

Pulses and Nuts

These foods have a high protein content and are good sources of minerals and vitamins of the B group (particularly thiamine). Their proteins supplement rice proteins. In nearly all rice-eating countries some pulses are taken as part of the daily diet. Their importance as a source of protein may be illustrated as follows: Suppose a man of 55 kg. body weight, who needs some 2,400 calories per day, consumes 500 grams of rice. This will provide him with 1,700 calories and 40 grams of protein. Fifty grams of pulses containing 20 percent protein will provide an additional 10 grams of protein. If daily physiological requirements of protein for an individual are estimated as 55 to 60 grams, only 5 to 10 additional grams will be required from other sources such as vegetables, roots, and animal products. A relatively small quantity of pulses can, therefore, contribute substantially to the protein content of rice diets and help to fulfill protein requirements. This applies not only to adults but also to growing children whose needs of calories and proteins per kilogram of body weight are greater than those of adults.

Pulses can be grown on relatively dry and unfertile land, and, as is well known, they increase the fertility of the soil. There are several species and numerous varieties. While there are usually strong local preferences in rice-eating countries for particular kinds of pulses, the possibility of "interchange" could with advantage be explored. In general, the pulses have received too little attention from agricultural departments and research workers; much

might be done by the development of improved strains, or the introduction of relatively unfamiliar pulses into areas particularly suitable for their cultivation but in which they were not previously grown. A greater intake of pulses will improve the nutritive value of rice diets and can be brought about more easily than an increase in the consumption of meat, milk, or eggs. The problems to be solved are less fundamental.

Special reference should be made to one important pulse, soya bean, which has a high protein content (30 to 40 percent), and is also, unlike other pulses except peanut, rich in fat. Its fat content may be as high as 18 percent. In the United States of America the production of soya bean has risen from 136,000 metric tons to 5.4 million metric tons during the last two decades. While the greater part of the crop is used as a source of edible oil, feed, and industrial raw material, the use of processed soya-bean products for human food has also risen in the United States, 188,000 metric tons of these products having been manufactured in 1947. Through the application of modern technology, soya bean has been introduced in increasing quantities into the diet of the population of the United States and other Western countries.

In certain countries in East Asia soya bean is a familiar food and an important item in the daily diet. In China, for example, it is eaten as a flour mixed with cereals or in the form of sauce, soya-bean "milk," sprouted soya bean, "curd," and cheese. In Java it is usually consumed as "tempe."² In general, however, soya bean and its products have proved unpopular when introduced into countries where they are unfamiliar and suitable methods of preparation are unknown. This may be due in part to ordinary prejudice against unfamiliar foods. Soya bean cooked in the same way as other pulses is, however, somewhat unpalatable because of certain bitter substances which the bean contains and there is some evidence that whole soya bean is not very digestible after ordinary boiling. Soya bean, in the form of processed flour from which the fat and bitter substances have been removed, might be introduced into rice-eating countries where it is not at present eaten. Recent investigations suggest that the "availability" of certain amino acids in soya-bean flour can be increased by some methods of heating, e.g., roasting and cooking under pressure. Alternatively, suitable methods of preparation, based on the traditional methods followed in such countries as China, might be demonstrated and popularized.

These and other problems must be studied and attacked if the use of soya bean in rice-eating regions is to be extended. Little will be achieved by mere exhortation to consume soya bean because it is a food exceptionally rich in protein. It may be added that the Nutrition Advisory Committee of the Indian Research Fund Association, after extensive study of the problem in its various aspects, reached the conclusion that soya bean has no special advantage over

² "Tempe" is a highly digestible product prepared by inoculating washed and cooked soya bean with a certain fungus. The inoculated beans are spread in thin layers between banana leaves and kept for one or two days. The resulting preparation is a grayish-white cake formed of the beans held together by the abundant mass of fungus mycelium.

common Indian pulses as a supplement to typical Indian diets based on cereals and adequate in quantity, and the Committee did not feel justified in advocating *immediately* the encouragement of the production of soya bean on a wide scale in India, as a substitute for pulses now in common use (60).

The Baguio Nutrition Committee commented on "emulsions of pulses such as the so-called soya-bean 'milk'," as follows:

"Emulsions of soya bean are usually prepared so that they contain approximately the same proportion of protein as cow's milk, and about three times as much vitamin B₁, but they lack vitamins A and D and are poor in riboflavin and calcium. More research is needed to produce a good pulse emulsion which can be a nutritive food for vast numbers of children pending the development of dairy industries. It is to be noted that an easily emulsified powder is required, since it would be impossible to distribute liquid pulse emulsions to distant areas."

Pulse emulsions are not in the nutritional sense a substitute for animal milk, and the term "milk" should not normally be applied to them. Minerals and vitamins can, however, be added in suitable proportions in various ways, and the nutritive value of the mixture brought close to that of animal milk.

The peanut or ground nut is extensively grown in various tropical rice-producing areas. Normally peanuts are not eaten as such in large quantities; their main importance is as a source of edible oil, and the residue or cake left after extraction of the oil is used as cattle food or manure. Peanuts are rich in both protein and fat and are a good source of some of the B vitamins, notably thiamine and niacin. The whole nuts themselves are usually eaten only in somewhat small amounts because their high fat content makes them indigestible and "cloying." Peanut cake as usually produced is unattractive in appearance and retains a fair amount of fat which affects its keeping qualities. An improved and more acceptable product is needed for human consumption, and the possibility of making greater use of such a product, particularly during the present food shortage, is worth consideration. Improved and "refined" cake of good quality can be mixed with cereal flours in a small percentage without seriously affecting the taste of the flours. In West Africa peanuts are eaten in fairly large quantities and methods of preparation and recipes used in this part of the world might be popularized elsewhere.

Vegetable fats and oils are obtained from coconuts and a variety of oil-bearing seeds. Some of these, e.g., coconuts, provide other nutrients besides fat. The Baguio Nutrition Committee expressed the opinion that the value of coconut in various forms as a supplement to rice diets has been insufficiently investigated and suggested that more attention should be given to this subject by nutrition research workers. Dried coconut has a fairly high protein content.

Red palm oil from the palm *Elaeis guineensis* is a rich source of provitamin A and is comparable in vitamin A potency to cod liver oil. It is a popular food in some parts of Africa and during recent years efforts have been made to encourage its use in certain countries in the East. Blended with other

vegetable oils, it has been successfully introduced into the diet of a few hospitals and institutions. Unfortunately its taste and color do not appeal to rice eaters in general. "Refining" processes which remove the red color and improve its taste impair its vitamin A activity, the latter being associated with the substance (carotene) giving it its characteristic natural color.

Typical rice diets are low in fat and nearly all the fat they contain is derived from vegetable sources. Little real knowledge is available about human fat requirements and at present it is difficult to assess the importance of the rice eater's small intake of this nutrient. Some nutrition workers hold the view that a greater intake of fat, both animal and vegetable, is needed in rice-eating regions. On the other hand, needs of fat are probably lower in tropical countries than in colder countries. More research is needed on this subject, as on many others touched on in this report. The comments of the Baguio Nutrition Committee were quoted on page 32.

Vegetables and Fruits

Vegetables are part of the daily diet in rice-eating countries and a supplementary food of great importance. Fruits are in general consumed more rarely and in small quantities—with the exception of starchy fruits such as bananas in some areas. Vegetables and fruits are of value as sources of provitamin A (carotene), ascorbic acid, and certain other nutrients. Many plant products are very rich in provitamin A. The provitamin A content of cassava leaves and sweet potato leaves, for example, may be up to 10,000 international units per 100 grams, and numerous other leafy vegetables commonly consumed in rice-eating areas contain amounts of a similar order. Among tropical fruits, the papaya and the mango are particularly rich in provitamin A; tomatoes, certain varieties of bananas, and some citrus fruits are good, though less potent, sources. Yellow corn may contain up to 700 international units of vitamin A activity per 100 grams, and certain varieties of yellow sweet potatoes up to 10,000. Mention has already been made of red palm oil as a substance very rich in provitamin A.

Vegetables and fruits are the principal sources of ascorbic acid in the diet in rice-eating regions as in most other parts of the world. Certain roots and tubers (e.g., potatoes and sweet potatoes) and also red peppers supply this vitamin in useful amounts. Red peppers may be of particular importance as a source of ascorbic acid in areas in which supplies of fruits and vegetables are limited. Special reference should be made in this connection to sprouted pulses. It is well known that pulses, which in the dry state are devoid or almost devoid of ascorbic acid, become rich in this vitamin on germination. The habit of consuming germinated pulses, mostly as salads or vegetables, is common in rice-eating areas. Ascorbic acid is developed in seeds in general during germination—in cereal grains, for example—but seeds other than pulses are rarely eaten in the germinated state. Sprouted pulses supply not only ascorbic acid but also protein, and should be regarded as a useful and important food in rice-eating areas.

Much ascorbic acid may be lost in the cooking of fruits, vegetables, and germinated pulses. The effect of different methods of cooking on the ascorbic acid content of such foods has been investigated in some detail in nutrition research laboratories in different countries. People must be educated to use methods which conserve this vitamin to the greatest possible extent.

Green leafy vegetables are good sources of calcium, a nutrient in which typical rice diets are deficient. They also supply some protein; for example, tender cassava leaves may contain 6 to 7 percent of crude protein of which 75 percent is true protein of high biological value. Other leafy vegetables have a similar protein content. Such vegetables must, however, be eaten in fairly large quantities, i.e., 100 grams daily or more, if they are to make a useful contribution to protein and calcium requirements.

Vegetables and fruits can be grown in abundance in tropical countries except in very dry areas and seasons. An increase in production and consumption is perfectly feasible, both because of ease of cultivation, and because the economic and other factors (including population pressure) which limit the production of animal foods affect vegetable and fruit production less strongly. In a tropical climate several crops of vegetables can often be raised annually from the same plot of ground and a high yield of nutrients can be obtained in this way per unit of area. There is a limit to the quantity of vegetables which can be eaten daily, because they are bulky foods. It is noteworthy, however, that the consumption of vegetables in China is greater than in many other countries in East Asia—India, for example. A general increase in consumption to the Chinese level can be safely advocated. A greater intake of both vegetables and fruits will help to improve poor rice diets and should be one of the immediate objectives of food and nutrition policy in most rice-eating areas.

Rice Polishings and Food Yeast

Rice polishings obtained during the milling of ordinary raw rice are of high nutritive value. Their protein content ranges between 10 and 18 percent and their fat content between 8 and 20 percent. They are also rich in iron. Per gram they may contain 30 to 50 micrograms of thiamine (10 to 15 times as much as husked rice and often more than 50 times as much as milled rice), 0.1 to 0.2 milligrams of niacin, and 1.5 to 3.5 micrograms of riboflavin (61). Rice polishings have been used as a source of thiamine for the treatment of beriberi. They may be given as such or used in the manufacture of concentrated preparations of thiamine, as in Java and the Philippines. The availability of synthetic thiamine has reduced their importance as a therapeutic agent against beriberi.

If husked rice is dried and freed of chaff (by treatment with blowers and exhausters), the polishings obtained during milling are reasonably palatable and if stored in a dry place can be kept for some months. If, however, the husked rice has a high moisture content before milling, the taste of the polishings and their keeping qualities are impaired, and, when eaten, the

polishings may cause intestinal irritation. Rice bran containing much husk is generally unsuitable for human consumption; in some regions more rice bran of this nature is produced in the mills than polishings which could be used as human food. For reasons given in an earlier section, polishings from parboiled rice have a considerably lower vitamin content than polishings from raw rice.

Rice polishings of good quality may be used in various ways and may be of special value in periods of food shortage and famine. In Java, bran obtained during home-pounding is winnowed, and a kind of porridge is prepared from it and given to small children. Rice polishings from rice mills in Java have been transported to Madura and used there in times of food shortage. Polishings can be used in soups, mixed with grated coconut, mixed with corn after fermentation, or added to various condiments. Quantities up to 20 or 40 grams can be taken daily. Rice polishings have the advantage of being a cheap food. If a practical use could be found for rice oil, polishings might be "extracted" in the same way as defatted soya-bean flour. The resulting product would have improved keeping qualities and would probably be more acceptable than untreated polishings.

The possibility of using dried yeast as a dietary supplement has received a good deal of attention during recent years. Dried yeast contains about 50 percent of crude protein ($N \times 6.25$), and of this about 80 percent is true protein of good biological value; the essential amino acid, methionine, is, however, present in yeast protein in a form largely unavailable to human beings. Dried yeast is a rich source of vitamins of the B group: per 100 grams its thiamine content ranges between 1.4 and 2.7 milligrams, and the corresponding figures for riboflavin, niacin, and pyridoxine are about 6, 40 to 45, and 4 to 8 milligrams respectively. The nutrient composition of yeast makes it a good supplement to diets consisting mainly of cereals, including poor rice diets.

Food yeast can be manufactured from cheap and simple starting materials, such as molasses or hydrolyzed cellulose (wood, sugar, and sulphite waste liquor), with ammonia salts or other cheap sources of nitrogen. During the growth of the yeast in suitable media containing such substances, valuable nutrients are synthesized; the effect is essentially that of transforming carbohydrate (e.g., the sugar in molasses) into protein and vitamins. In sugar-producing areas in the tropics molasses is often available in large quantities; it may be used in the manufacture of alcohol but is rarely consumed as human food. Dried yeast can also be produced as a by-product of breweries and distilleries but the quantities of brewers' yeast and distillery yeast which could be produced in the tropics are limited, and in certain respects (palatability, and nutrient content in the case of distillery yeast) they are less suitable for human consumption than food yeast manufactured by modern technical methods.

The use of food yeast as human food was first advocated in Germany during and after the First World War, and subsequently interest in this product ex-

tended to other countries. The Technical Committee on Nutrition of the League of Nations recommended (in 1938) the inclusion of yeast in certain tropical diets. Just before the Second World War food yeast was produced in Java with the object of introducing it into the Javanese diet. A pilot plant was set up in England during the war, after which plans were laid for the production of food yeast on a commercial scale in Jamaica, the project being undertaken by a firm known as "Colonial Food Yeast Limited." Three hundred tons of dried yeast were manufactured by this firm in 1947.

A small daily intake of 7 to 15 grams of food yeast is sufficient to supply additional protein and vitamins in useful quantities. Manufactured by primitive methods in prison camps in the Far East during the Japanese occupation, it was found to have a beneficial effect on conditions due to deficiencies of the B group of vitamins. Similar observations have been made in Nigeria, where the administration of 4 to 7 grams of food yeast daily for 5 to 7 weeks cured or improved cases suffering from vitamin B₂ deficiency states (62). In a trial with children in England, the daily consumption for 5 days weekly of a biscuit containing 8 grams of dried yeast was associated with an increase of the rate of growth (62).

Food yeast of good quality is reasonably palatable and has been taken regularly without difficulty by children and adults. Its use on any considerable scale in rice-eating regions raises, however, a number of problems. For example, there may be technical difficulties in its large-scale manufacture in tropical countries. Again, it would not be easy to persuade rice eaters to take food yeast regularly as part of their ordinary diet. Its most appropriate use would probably be in school-feeding programs and other kinds of communal feeding. It may also be used in improving the nutrition of groups (e.g., plantation laborers) suffering from deficiency states, and in the treatment of hospital outpatients and inpatients.

The Baguio Nutrition Committee pointed out that food yeast must be cheap if its use as a dietary supplement is to be extended. The price of food yeast which is at present being supplied to a limited extent to certain countries in the East is high.

It may be remarked in conclusion that until further trials have been made and more information becomes available, the practical contribution which food yeast can make to the improvement of poor rice diets cannot be satisfactorily assessed.

Calcium and Riboflavin

In the preceding sections the supplementation of rice diets by certain foods and food groups has been considered. The present section is devoted to two nutrients, calcium and riboflavin, which require special attention in a study of the nutritive value of rice and rice diets.

The amounts of calcium supplied by typical rice diets fall short of current estimates of calcium requirements. It is possible that the capacity of human beings to adapt themselves to a low calcium intake, particularly in tropical

climates, has been underestimated; this subject requires further investigation. There is evidence, however, that a greater intake of calcium will benefit rice eaters, particularly children and expectant and nursing women. Rice in any state is a poor source of calcium, but milled rice is particularly deficient. Milk has a high calcium content and in Western countries a large proportion of total calcium intake is obtained from this source. The difficulties of increasing supplies of milk in rice-eating areas have already been discussed. Reliance must be placed on other sources of calcium, at least in the immediate future.

In certain areas drinking water may contribute significantly to calcium intake, but this subject has not been investigated to any extent. For geological reasons, drinking water in the main rice-eating areas of India has a low content of lime.

Leafy vegetables are good sources of calcium, as has already been pointed out. Many such vegetables contain, however, rather large amounts of oxalic acid which tend to make the calcium partially insoluble and less available. Investigations on the availability of calcium in certain vegetables have been made in India (63). In experiments with adult males, the availability of calcium in pumpkin leaves (*Cucurbita pepo*) was found to be high; at an intake level of 100 to 200 grams of the leaves daily, supplying 250 to 500 mg. of calcium, the calcium was better utilized than the calcium in milk. Similar experiments with cabbage (*Brassica oleracea capitata*), ladies-fingers (*Hibiscus esculentus*) and drumstick (*Moringa oleifera*) and amaranth (*Amaranthus gangeticus*) showed that calcium from these sources was well utilized, though not to the same extent as calcium in milk. It may be noted that amaranth leaves are rich in oxalic acid. The amounts of various vegetables given in these experiments was considerably larger than the amounts normally included in ordinary diets.

Experiments in China (64) support the conclusion that the calcium in leafy vegetables, with the exception of spinach, is well utilized.

Small fish eaten with the bones or preparations of larger fish containing ground bones are a better source of calcium than leafy vegetables. It has been reported (58) that a daily intake of 70 grams of small fish added nearly 400 mg. of calcium to the diet, of which about 70 percent was retained. The chewing of betel leaves with lime is a common habit in the East and may contribute useful amounts of calcium. It has been shown that calcium taken in this way is well utilized (59); the amount of calcium ingested in chewing six betel leaves was equivalent to that obtained from ten ounces (0.28 liter) of cow's milk.

Calcium may be obtained directly in other ways. In Indo-China, for example, there is a rice product known as "banh-duc" (65) which is a kind of "rice bread" prepared by grinding soaked glutinous rice in about five times its weight of water rich in lime. The product is cooked for about thirty minutes until it becomes a pasty mass; about one percent of salt is added and the mixture is beaten on a wooden platter and allowed to cool. The final product is rich in calcium, containing at least 30 times as much calcium as ordinary rice; it is not, however, eaten frequently or in large amounts. In the report of the

Rice Study Group (1) so-called "calcured" rice is mentioned. This is a sort of parboiled rice treated with a hot dilute solution of calcium chloride. It is claimed that "calcured" rice has a better appearance and better keeping qualities than ordinary parboiled rice, but there is as yet no published evidence in support of these statements. The Nutrition Advisory Committee of the Indian Research Fund Association, in the Report of its 14th Meeting (New Delhi, 1946) recommended that the effect of treating rice with calcium salts during the parboiling process should be investigated.

It is of interest to note that in many parts of South and Central America where corn is soaked in lime water to soften it during household preparation the calcium content of the corn as consumed is greatly increased.

In certain circumstances additional calcium may be supplied directly in the form of a calcium salt (e.g., calcium lactate). This had beneficial results when tried in an experiment with day-school children in India (66). The possibilities of supplying additional calcium as a calcium salt to school children through school-feeding programs is worth consideration. The calcium salt might be given mixed in suitable quantities with the ingredients included in the meal.

Riboflavin deficiency is common in rice-eating regions. Milk, which is not generally available, is among the richest sources of this nutrient. Green leafy vegetables and pulses contain riboflavin but would have to be eaten in large amounts to raise intake of riboflavin to levels generally recommended by nutrition workers. It will be recalled that "enriched" rice, as prepared by current methods, does not supply additional riboflavin.

The above comments on calcium and riboflavin may be illustrated and extended by reference to Table 21. This shows a diet based on rice and supplying 2,500 calories, which is superior in various respects to typical rice diets. The rice is in the form of home-pounded, undermilled, or parboiled rice, and foods other than rice are included in greater quantities than is usual in rice-eating regions. While it contains no milk, the diet can be regarded as an "improved" rice diet, and in drawing it up consideration has been given to most of the methods of improving rice diets discussed in this survey. If such a diet were generally consumed in rice-eating regions, the result would be a very definite change for the better in state of nutrition. In the table the quantities of certain nutrients in the "improved" diet are compared with a series of "Recommended Allowances" put forward by the Food and Nutrition Board, National Research Council, U.S.A. (67). The "improved" rice diet will supply protein and thiamine in amounts which compare satisfactorily with the "Recommended Allowances," and its vitamin A content is more than sufficient to cover requirements of this vitamin. As regards calcium and riboflavin content, however, it falls short of the "Recommended Allowances." The "Allowances" quoted are those considered appropriate for a 70 kg. man engaged in sedentary work. The gulf between the quantities of calcium and riboflavin which could be supplied by the "improved" rice diet to children, and the high "Recommended Allowances" for children of these nutrients, is considerably wider.

VII Conclusion

No attempt has been made in this survey to cover each aspect of the subject in detail or to quote all the relevant literature. The picture which emerges is, however, clear enough in its broad outlines. Poor rice diets are unsatisfactory because they contain too much rice and because the nutrient content of rice is reduced in various ways between harvesting and consumption. They can be improved by the addition of foods which supply nutrients lacking in rice and by improving or enhancing the nutrient value of rice itself.

The Baguio Nutrition Committee declared that the time has come for a new and vigorous campaign to raise nutritional levels in rice-eating countries. How can this best be organized and along what lines should it progress?

In the first place, more research is needed. It has been pointed out again and again in this survey that existing knowledge is inadequate at many points. In some countries personnel, laboratories, and institutes concerned with nutrition research are already available and a basis exists for further extension; in others less attention has been given to problems of nutrition. There is clearly need for more trained nutrition research workers, units and laboratories in rice-eating areas in general.

Secondly, machinery and personnel are required to develop practical nutrition programs. National nutrition organizations and committees can greatly assist such development. The establishment of these bodies in each member country of FAO has been strongly recommended by the Hot Springs Conference and by other FAO conferences. Any practical measure for improving nutrition, e.g., school feeding, the introduction of some unfamiliar kind of rice of higher nutrient content, educational programs, etc., must be organized and supervised by government departments, and here again trained personnel is needed. Various international conferences have suggested that, in view of the close association between nutrition and health, all public health departments should include a nutrition section headed by a well-trained nutrition worker. This is one method of hastening progress, but there are many others.

There is now a shortage of rice and other foods in the rice-eating regions in general, and governments are naturally preoccupied with urgent problems of supply. It may be argued that since "enough food" is all-important, projects for raising nutritional levels cannot appropriately be considered at the present time. Nutritional knowledge and the help of nutrition workers are, however, needed to ensure that the best use is made of available food supplies. To give a practical example: considerable losses of calories and nutrients result from faulty methods of washing and cooking rice, and the reduction of such losses would increase total food supplies. This is a problem which falls within the

sphere of the nutrition worker, who can also help in organizing relief programs on a satisfactory basis. Apart from immediate practical measures of this kind, plans must now be laid for improving nutrition when the present period of acute shortage is past.

Governments have the responsibility of initiating nutritional programs adapted to the needs and circumstances of their peoples; these programs should be based on nutrition research and the recommendations of nutrition experts familiar with local conditions. The most promising methods of improving rice diets may differ from country to country. There is, however, sufficient similarity in the basic problems of nutrition throughout the rice-eating regions to enable one country to profit from experience in others. FAO can encourage and assist governments to initiate suitable measures and observe and report on the results achieved for the benefit of all rice-eating countries. Its task is to stimulate and to co-ordinate. The machinery to be established for this purpose includes an FAO regional office in East Asia and an International Rice Council with headquarters in this region. Associated in various ways with these will be bodies concerned with specific technical subjects, e.g., fisheries, rice production and conservation, and nutrition. The Baguio Nutrition Committee recommended that a committee of nutrition workers from East Asia should be convened annually with the following functions and scope:

- (a) The discussion of problems of common interest to the various countries, so that information may be pooled and work in the region co-ordinated.
- (b) Reviewing the development of national nutrition programs and the program of the FAO regional organization in this field.
- (c) Advising countries in this region on nutritional questions through the regional FAO organization.

Since rice eaters form the majority of mankind, the improvement of rice diets is perhaps the most important of all the vast problems with which FAO is concerned.

Finally, it must be emphasized that the attack on malnutrition cannot succeed unless it is an integral part of an energetic attack on poverty and ignorance on the broadest possible front. The improvement of nutrition is largely dependent on agricultural, industrial, and social development. Conversely, better nutrition means better health, better capacity to learn, and better capacity for work and can therefore hasten progress and development in general.

Summary

1. Undernutrition, malnutrition, and deficiency diseases are common in rice-eating countries. The association between beriberi and the excessive consumption of milled rice has been recognized for fifty years, but the disease has not been eradicated. The improvement of rice diets is a wider problem than the prevention of beriberi.

2. "Whole" rice resembles in its nutrient content other cereals in a similar state. Milling and household preparation lead to serious losses of nutrients.

3. Undermilled, parboiled, and enriched rice provide nutrients lacking in milled raw rice. Improvement in the cleanliness of rice as sold, and the education of the population in better methods of household preparation, will reduce losses occurring as a result of washing and cooking.

4. Typical rice diets contain too much rice in proportion to other foods and are deficient in vitamins of the B group, vitamin A, calcium, and protein. Supplements and substitutes which provide these nutrients are needed in greater quantities. Larger supplies of fish, vegetables, and pulses could readily be made available. It may be nutritionally advantageous to replace milled rice partially by other cereal products which have not been depleted of nutrients to the same degree by milling; excessive replacement of rice by cassava is, however, undesirable, because of the low protein content of the latter. Other supplementary foods which may be of value include food yeast and rice polishings.

5. Because of existing agricultural conditions, population pressure on land, and the poverty of rice-eating countries, a substantial increase in the supply of milk, meat, and eggs is scarcely feasible in the immediate future.

6. The deficiency of rice diets in calcium and riboflavin is particularly difficult to correct. Intake of these nutrients can, however, be increased in various ways, e.g., by the greater consumption of leafy vegetables.

7. While the most effective methods of improving the nutritive value of rice and rice diets may differ with locality, there is an essential similarity in basic nutrition problems in rice-eating countries. FAO will do what it can to help these countries to increase food supplies and improve nutrition, and hopes to organize a co-ordinated attack on malnutrition among rice eaters through suitable regional developments.

TABLE 1.—BERIBERI IN VARIOUS EASTERN COUNTRIES

Year	Madras Presidency (India)				Japan Pop. 70 million		Philippines Pop. 14 million	
	Northern Circars Pop. 13.9 million		Remainder Pop. 32.9 million					
	Hospital Cases	Deaths	Hospital Cases	Deaths	Deaths		Deaths	
					Infant	Adult	Infant	Adult
1930	.....	.....	.....	...	8,649	6,807	16,485	5,089
1931	.....	.....	.....	...	8,277	7,142	15,018	4,520
1932	16,091	93	665	3	9,770	7,997	13,302	3,871
1933	20,513	55	822	2	7,162	4,643	14,720	3,962
1934	21,849	42	711	5	8,074	5,754	17,054	4,365
1935	34,639	89	382	8	6,720	4,774	14,299	4,315
1936	20,814	94	452	7	—	—	11,316	3,506
1937	27,488	65	748	5	6,791	4,306	13,004	3,793
1938	32,717	64	649	4	—	—	13,217	3,833
1939	.....	.....	.....	...	.....	...	14,612	2,561
1940	.....	.....	.....	...	.....	...	14,227	2,605
1946	.....	.....	.....	...	.....	...	18,582	4,567

NOTE: The above figures are quoted simply to illustrate the fact that the beriberi problem has not yet been solved. They are unquestionably inaccurate and could not be used to compare the incidence of beriberi in the different countries. No data for India and Japan later than 1938/39 are available to the writers of this survey. The difference in the reported number of hospital cases and deaths in the Northern Circars District of the Madras Presidency and the remainder of the province is related to the fact that highly milled raw rice was generally consumed in the former and parboiled rice in the latter (30).

No statistics of beriberi in China are available. The disease is, however, known to be prevalent in South China where rice is consumed. It was reported that 3 to 7 percent of patients in hospitals in Nanking, Shanghai, Foochow, Canton, and Hong Kong had beriberi previous to the outbreak of war with Japan in 1937; after the war had begun the incidence increased to 15 percent. The disease was particularly common in pregnant women (68).

TABLE 2.—RICE DIETS IN VARIOUS COUNTRIES
(per caput per day)

Rice Diets	China ¹ (Shanghai)	India ²	Philippines ³	Western Java ⁴
	Gm.	Gm.	Gm.	Gm.
Rice.....	359	477	408	585
Other cereals.....	69	Negligible	Negligible	Negligible
Pulses.....	28	32	14	6
Vegetables.....	218	34	165	57
Fat and oil.....	27	3	Unrecorded	1
Fish.....	30	Negligible	145	20
Meat.....	31	2	21	1
Milk, egg.....	5	Negligible	Negligible	Negligible
Fruit.....	30	11	19	17
Sugar.....	4	Negligible	18	Negligible
Total calories.....	2020	2000	2038	2100
Total protein.....	55	40	75	51

¹Bureau of Social Affairs, The City Government of Greater Shanghai. *Standard of Living of Shanghai Laborers*. Shanghai: Chunghua Book Company, 1934.

²W.R. Aykroyd *et al.* "The Rice Problem in India," *Indian Medical Research Memoirs*, No. 321, 1940.

³Report of the Philippine Delegation to the FAO Conference in Baguio, February 1948.

⁴Unpublished data from the Institute of Nutrition, Batavia, Java.

NOTE: The above figures are based on the study of relatively small groups and do not represent average food consumption in the different countries. They cannot be used to draw comparisons between the countries in question. For example, the quantities of fish and meat included in the diet of the Shanghai laborers is probably above the average for the rice-eating areas of China as a whole, and in parts of India the diet of poor rice eaters in normal times may contain more fish, fruit, and sugar than the table indicates. The figures are quoted to give a general idea of the nature of rice diets in East Asia and to show the preponderance of rice in such diets.

TABLE 3.—AVERAGE COMPOSITION OF RICE, WHEAT, AND CORN

Components	Rice		Wheat		Corn
	Husked	Milled	Whole	White Flour	Whole
100 calorie portions (in grams).....	28.0	29.0	28.0	28.0	27.0
Protein (percent).....	8.9	7.6	11.1	9.3	10.0
Fat (percent).....	2.0	0.3	1.7	1.0	4.3
Carbohydrate (percent)...	77.2	79.4	75.5	77.2	73.4
Fuel value per hundred grams (in calories).....	356.0	351.0	362.0	355.0	372.0
Ash (percent).....	1.90	0.4	1.8	0.5	1.50
Fiber (percent).....	1.0	0.2	2.4	0.4	2.3
Vitamins (parts per million)					
Ascorbic Acid.....	0	0	0	—	0
Thiamine.....	3-5	0.6-1.0	3.2-7.7	0.87	4.4
Riboflavin.....	.8-1.0	0.28	1-1.2	0.40	1.3-1.5
Nicotinic acid.....	55	15-20	53	10.00	21*
Pantothenic acid.....	17	6.4	13.4	5.70	8*
Pyridoxine.....	10.3	4.5	4.6	2.20	—
Choline chloride.....	—	880	920	520	370*
Vitamin A (international units per gram).....	.5-1.0	0	0.2-0.25	—	0.† 7-7.5*
Tocopherol.....	—	—	9.10	0.30	25.0† 31.0*
Minerals (percent)					
Calcium.....	0.084	0.009	0.50	0.020	0.015
Magnesium.....	0.119	0.028	0.170	—	0.160
Potassium.....	0.342	0.079	0.480	—	0.400
Sodium.....	0.078	0.028	0.100	—	0.050
Phosphorus.....	0.290	0.096	0.400	0.092	0.430
Chlorine.....	0.023	0.006	0.090	—	0.02
Sulfur.....	—	—	0.180	—	0.140
Iron.....	0.0020	0.0009	0.004	0.00084	0.003
Manganese (parts per million).....	—	10.14	45.91	—	6.83
Copper (parts per million).....	3.60	1.90	7.87	1.70	4.49

*yellow

†white

SOURCE: M.C. Kik and R.R. Williams, *The Nutritional Improvement of White Rice* (National Research Council, Bulletin No. 112), 1945.

TABLE 4.—APPROXIMATE AMINO-ACID CONTENT OF THE PROTEINS OF CEREAL GRAINS (CALCULATED TO 16.0 GRAMS OF NITROGEN)¹

Amino Acids	Whole Wheat	Whole Maize	White (milled) Rice
	Gm.	Gm.	Gm.
Arginine.....	4.2	4.8	7.2
Histidine.....	2.1	2.2	1.5
Lysine.....	2.7	2.0	3.2
Tyrosine.....	4.4	5.5	5.6
Tryptophane.....	1.2	0.8	1.3
Phenylalanine.....	5.7	5.0	6.7
Cystine.....	1.8	1.5	1.4
Methionine.....	2.5	3.1	3.4
Threonine.....	3.3	3.7	4.1
Leucine.....	6.8	22.0	9.0
Isoleucine.....	3.6	4.0	5.3
Valine.....	4.5	5.0	6.3
Glycine.....	—	—	10.3

¹Equal to about 95 grams of protein.

SOURCE: R. J. Block and H. H. Mitchell, *Nutrition Abstract Review*, 16: 249, 1946.

TABLE 5.—AVERAGE THIAMINE, RIBOFLAVIN, AND NIACIN CONTENT OF RICE (HUSKED AND MILLED)—13 VARIETIES

Type and Number of Samples	Thiamine	Riboflavin	Niacin
	(. Micrograms/grams)		
Husked (44).....	3.55	.60	53.08
Milled (45).....	.84	.26	19.62

SOURCE: M.C. Kik and R.R. Williams, *The Nutritional Improvement of White Rice* (National Research Council, Bulletin No. 112), 1945.

TABLE 6.—COMPARISON OF THE VITAMIN CONTENT OF THE MILLED FRACTIONS OF SEVERAL VARIETIES OF RICE¹

Vitamin	Number of Samples of Husked Rice	Milled Fraction					
		Husked Rice	1st Break	2nd Break	"Finished"	Bran	Polish
		(..... <i>Micrograms/gram</i>)					
Thiamine.....	3	4.2	1.7	1.2	0.8	27.9	23.3
Nicotinic Acid.	3	47.2	25.8	21.7	12.7	408.6	384.7
Pantothenic Acid.....	3	17.0	9.1	7.7	6.4	71.3	92.5
Pyridoxine....	3	10.3	6.9	5.1	4.5	32.1	30.8
Riboflavin....	17	0.61	0.42	0.33	0.24	2.14	1.78
Biotin.....	17	0.121	0.066	0.056	0.042	0.468	0.656

¹All figures represent the averages of a number of samples and refer to dry weight. The description of the fractions is not based on the definitions given in the introduction of this report.

SOURCE: V.R. Williams, W.C. Knox, and E.A. Fieger, *Cereal Chemistry*, 20: 560, 1943, and 21:540, 1944.

TABLE 7.—THIAMINE, RIBOFLAVIN, AND NIACIN CONTENTS OF RICE VARIETIES GROWN IN ARKANSAS, LOUISIANA, TEXAS, AND CALIFORNIA, MAIN EXPERIMENT STATIONS, 1941-42

Variety	Arkansas			Louisiana			Texas			California		
	Thia- mine	Ribo- flavin	Niacin	Thia- mine	Ribo- flavin	Niacin	Thia- mine	Ribo- flavin	Niacin	Thia- mine	Ribo- flavin	Niacin
	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)
Early Prolific.....	4.20	0.64	47.8	4.40	0.54	39.3	4.00	0.61	46.3	3.16	0.50	40.0
Caloro.....	4.00	.54	46.0	4.00	.76	49.6	—	—	—	2.87	.66	52.6
Arkrose.....	4.20	.60	55.7	4.00	.63	48.6	—	—	—	—	—	—
Acadia.....	3.80	.60	40.0	4.09	.83	41.3	—	—	—	—	—	—
Prelude.....	3.31	.64	41.5	3.75	.66	43.2	—	—	—	—	—	—
Supreme Blue Rose.....	3.55	.57	46.0	—	—	—	—	—	—	—	—	—
Improved Blue Rose.....	4.15	.59	—	—	—	50.1	—	—	46.5	—	—	—
Blue Rose.....	—	—	—	—	—	—	5.06	.51	40.6	—	—	—
Blue Rose.....	—	—	—	—	—	—	3.46	.54	44.2	—	—	—
Lady Wright.....	4.55	.58	43.0	4.06	.52	41.0	3.58	.52	—	2.75	.66	45.0
Nira.....	4.63	.62	40.0	4.74	.60	45.1	3.30	.47	47.0	5.05	.43	46.7
Arkansas Fortuna.....	4.63	.62	52.1	4.13	.63	46.6	—	—	—	—	—	—
Zenith.....	3.75	.47	53.3	3.63	.64	56.8	4.00	.52	52.0	3.52	.68	48.6
Japan.....	—	—	—	—	—	—	3.46	.74	52.4	—	—	—

SOURCE: M.C. Kik, University of Arkansas Agricultural Experiment Station, *Bulletin No. 458*, 1945.

TABLE 8.—NUTRIENTS IN UNDERMILLED RICE

Sample Number	Variety	Thiamine	Riboflavin	Niacin
		<i>Mg./lb.</i>	<i>Mg./lb.</i>	<i>Mg./lb.</i>
11.....	Zenith.....	1.21	.19	11.97
3.....	Early Prolific.....	.96	.23	14.90
1.....	Early Prolific.....	.96	.22	8.55
16.....	Rexoro.....	.86	.26	14.54
6.....	Fortuna.....	.86	.23	14.40
10.....	Zenith.....	.78	.16	11.03
18.....	Nira.....	.74	.25	11.03
15.....	Blue Rose.....	.72	.25	11.79
4.....	Early Prolific.....	.71	.17	12.15
13.....	Zenith.....	.70	.18	11.07
17.....	Rexoro.....	.68	.23	11.97
2.....	Early Prolific.....	.68	.20	8.10
14.....	Zenith.....	.63	.23	13.61
12.....	Early Prolific.....	.63	.18	11.48
5.....	Lady Wright.....	.50	.18	10.08
8.....	Lady Wright.....	.48	.17	13.50
7.....	Fortuna.....	.45	.17	13.86
9.....	Fortuna.....	.44	.17	10.13

SOURCE: M.C. Kik and R.R. Williams, *The Nutritional Improvement of White Rice* (National Research Council, Bulletin No. 112), 1945.

TABLE 9.—COMPOSITION OF RICE BEFORE AND AFTER MILLING
WITH PERCENTAGE LOSS IN WEIGHT OF CONSTITUENTS

Average of 5 Samples	Mois- ture	On Moisture-free Basis					Weight per 1,000 kernels
		Fat	Crude Fiber	Ash	Protein (Nx6.25)	Carbo- hydrates	
Composition of unmilled rice (brown)	(.....Percent).....						Gm.
	9.26	2.45	0.88	1.22	8.67	86.67	20.11
Composition of white rice	9.37	0.37	0.16	0.36	8.15	90.79	18.24
Losses on polishing...	—	86.1	83.7	73.2	14.9	5.7	9.5

SOURCE: B.S. Platt, *Nutrition in the Colonial Empire*, First Report, Part I (1939), p. 186.

TABLE 10.—THIAMINE CONTENT OF DIFFERENT FRACTIONS OF RICE

Products	Thiamine (micrograms/grams)				
	Total	Bound		Free	
			Percent		Percent
Paddy or rough rice.....	3.60	1.07	29.6	2.53	70.4
From milling or bleaching process:					
Whole brown.....	4.00	1.78	44.6	2.22	55.4
First-break huller.....	.88	.08	9.0	.80	91.0
Second-break huller.....	.87	.32	36.8	36.56	63.2
Pearling cone.....	.83	.31	37.3	37.52	62.7
Brush.....	.80	.34	42.5	.46	57.5
Finished, clean, polished rice:					
Head rice.....	.74	.16	21.6	.60	78.4
Second head.....	.46	.12	26.1	.34	73.9
Screening.....	.91	.43	47.2	.48	52.8
Brewers'.....	1.35	.35	26.0	1.00	74.0
Rice by-products:					
Hulls.....	1.23	.53	43.1	.70	56.9
First-break bran.....	33.00	8.10	24.5	24.90	75.5
Second-break bran.....	24.50	3.30	13.4	21.20	86.6
Pearling-cone polish.....	26.50	5.30	20.8	21.20	79.2
Brush polish.....	27.90	3.10	11.0	24.80	89.0

SOURCE: M.C. Kik, Table "Thiamine (total, free, and bound) in products of commercial rice mill-
ing, Main Experiment Station, 1942," University of Arkansas Agricultural Experiment Station, *Bulletin*
No. 458, 1945.

TABLE 11.—EFFECT OF WASHING ON THE THIAMINE, RIBOFLAVIN, AND NIACIN CONTENT OF RICE

Form of Rice	Thiamine			Riboflavin			Niacin		
	Before	After	Loss	Before	After	Loss	Before	After	Loss
	(Micrograms/gram)	(Micrograms/gram)	Percent	(Micrograms/gram)	(Micrograms/gram)	Percent	(Micrograms/gram)	(Micrograms/gram)	Percent
Husked (brown).....	4.40	3.47	21.14	.65	.60	7.70	54.00	47.00	13.00
Milled (white).....	.65	.37	43.07	.27	.20	25.92	20.57	15.83	23.04
Malekized (parboiled).....	2.01	1.70	15.42	.40	.34	15.00	40.20	35.00	13.00
Converted (parboiled).....	3.02	2.82	6.62	.41	.36	12.19	49.00	44.00	10.20
Earle (undermilled).....	2.94	2.75	6.46	.38	.34	10.52	50.00	42.00	16.00

SOURCE: M.C. Kik and R.R. Williams, *The Nutritional Improvement of White Rice* (National Research Council, Bulletin No. 112), 1945.

TABLE 12.—DIGESTIBILITY AND UTILIZATION OF RICE

Average mean (percent) digestibility					Calories from 100 grams of rice	
Form of Rice	Total Nitro- gen	Carbo- hydrate	Fat	Inorganic Sub- stances	Actual Quantity Utilized	Waste (as faeces)
	(.....Percent.....)				(....Calories...)	
<i>White</i>						
100 percent polished	85.79	99.68	86.81	90.88	315.99	4.83
70 percent polished	82.99	99.59	80.51	87.30	303.63	6.95
50 percent polished	81.98	99.29	74.35	84.36	283.55	10.19
Unpolished	74.86	98.61	58.27	77.98	273.50	19.72
Unpolished rice flour	—	—	—	—	282.01	12.00

SOURCE: B. S. Platt, *Nutrition in the Colonial Empire*, First Report, Part I (1939), p. 186.

NOTE: These figures are taken from "My Principle of Nutrition . . ." by T. Saiki (Tokyo, 1930), who refers to the work of Sugimoto on the problem. In general the data of Saiki and Sugimoto on the digestibility of "polished" rice agree well with those of Langworthy and Deuel (69). The term "polished" as used in the above table does not correspond with the definition adopted in this survey.

TABLE 13.—EFFECT OF SOAKING, WASHING, AND STEAMING ON THE THIAMINE CONTENT OF HUSKED, UNDERMILLED, HOME-POUNDED AND MILLED RICE

Treatment	Husked Rice	Undermilled or Home-pounded Rice	Milled Rice
	(.....Micrograms/gram ¹)		
Untreated	2.8-3.3	1.6-2.8	0.7-1.4
After washing	1.6-2.1	0.8-1.4	0.7
After steaming	—	1.6-2.8	0.7-1.4
After washing and steaming	1.6	0.5-0.8	0.7
After soaking and steaming	—	1.4-1.6	—
After cooking (with a little water)	—	1.6-2.8	0.7-0.9
After intensive washing	—	0.7	0.7

¹Converted values using the ratio 1 international unit of thiamine = 3.3 micrograms.

SOURCE: A.G. vanVeen, Health Organization, League of Nations, *Bulletin IX* (1940-41) 357.

TABLE 14.—EFFECT OF WASHING AND COOKING ON THE THIAMINE CONTENT OF RAW AND PARBOILED MILLED RICE

Sample Number	Vitamin B ₁ content (micrograms/gram)	Wash-Water (micrograms/gram of original rice)	Percentage loss in washings	Washed Rice (micrograms/gram by difference)	Cooked Rice Conjee (micrograms/gram of original rice)	Percentage of Vitamin B ₁ Present in Washed Rice Removed on Cooking
Raw milled						
(1.....)	1.0	0.6	60	0.4	0.2	25
(2.....)	1.2	0.6	50	0.6	0.3	33
AVERAGE.....	1.1	...	55	...	0.25	30
Parboiled milled						
(1.....)	1.9	0.2	10	1.7	1.2	25
(2.....)	2.4	0.2	8	2.2	1.6	25
AVERAGE.....	2.2	...	9	...	1.4	25

SOURCE: M. Swaminathan, *Indian Journal of Medical Research*, 30: 409, 1942.

TABLE 15.—EFFECT OF COOKING IN EXCESS WATER ON LOSS OF VITAMINS

Type of Rice and Method of Cooking	Cooking Time Minutes	Thiamine			Riboflavin			Niacin		
		Before (Micrograms/ gram)	After	Loss Percent	Before (Micrograms/ gram)	After	Loss Percent	Before (Micrograms/ gram)	After	Loss Percent
Brown										
Double boiler ¹	50	4.40	4.00	9.00	.81	.75	6.17	54.00	52.00	4.00
Open vessel ²	40	4.40	2.98	32.20	.81	.60	26.00	54.00	35.70	31.00
White										
Double boiler ¹	30	.65	.64	1.34	.27	.25	7.40	20.57	19.86	3.45
Open vessel ²	20	.65	.30	54.00	.27	.13	48.15	20.57	20.00	41.00
"Malekised" ³										
Double boiler.....	27	2.01	1.88	6.46	.40	.37	7.50	40.20	39.30	2.23
Open vessel.....	22	2.01	.86	57.21	.40	.20	50.00	40.20	25.00	37.80
"Earle" ⁴										
Double boiler.....	45	2.94	2.90	1.36	.38	.36	5.20	50.00	48.50	3.00
Open vessel.....	30	2.94	1.70	42.17	.38	.18	36.00	50.00	31.15	37.70
Converted										
Double boiler.....	30	3.02	2.86	5.30	.41	.30	7.30	49.00	48.50	2.04
Open vessel.....	22	3.02	1.70	43.71	.41	.29	29.44	49.00	30.60	37.55
Brand (enriched)										
Double boiler.....	30	3.00	2.90	3.33	.25	.23	8.00	20.00	19.20	4.00
Open vessel.....	20	3.00	1.63	45.66	.25	.16	36.00	20.00	12.00	40.00
White (enriched)										
Double boiler.....	30	1.40	1.36	2.85	.29	.27	6.80	19.50	18.62	4.51
Open vessel.....	20	1.40	.65	53.57	.29	.18	37.93	19.50	11.00	41.00
White (enriched)										
Double boiler.....	30	3.20	3.05	4.70	.32	.30	6.20	19.20	18.50	3.64
Open vessel.....	20	3.20	1.59	50.00	.32	.20	37.50	19.20	10.00	47.90
Brand (enriched)										
According to directions on container ³	20	3.00	1.09	63.70	.25	.17	32.00	19.20	10.00	47.00
Converted										
According to ⁴	20	3.02	2.44	19.21	.41	.30	26.83	49.00	38.18	25.12

¹One cup of rice and one and one-half cups of boiling water are placed in the top of a double boiler. All the water is absorbed and the cooked rice is not rinsed.
²One-half cup of rice is placed in an open vessel covered with eight cups of boiling water, cooked in a colander, and drained.
³One cupful of ——— "enriched" rice is placed in an open vessel with ten cupfuls of boiling water, cooked, placed in a colander, and drained.
⁴One cup of rice is cooked in one quart of boiling water, drained in a colander, and quickly rinsed in cold running water.
 SOURCE: M.C. Kik and R.R. Williams, *The Nutritional Improvement of White Rice* (National Research Council, Bulletin No. 112), 1945.

TABLE 16.—THIAMINE, RIBOFLAVIN, AND NIACIN IN MILLED PARBOILED AND MILLED RAW RICE

Variety	Thiamine		Riboflavin		Niacin	
	Milled Parboiled	Milled	Milled Parboiled	Milled	Milled Parboiled	Milled
	(.....Micrograms/gram.....)					
Nira ¹	1.35	.59	0.47	0.30	49.0	20.6
Coloro ²	1.61	.84	.33	.26	45.2	18.5
Indian ³	1.74	—	.30	—	45.0	—
Lady Wright ³	—	.57	—	.19	—	19.5
Supreme Blue Rose ³	—	.65	—	.25	—	18.9

¹ Obtained from Dr. C.R. Adair, Associate Agronomist, Bureau of Plant Industry, U.S. Department of Agriculture, Rice Branch Experiment Station, Stuttgart, Arkansas.

² Obtained from the Rice Growers Association of California, Sacramento, California.

³ Obtained from the Arkansas Rice Growers Cooperative Association, Stuttgart, Arkansas.

SOURCE: M. C. Kik, University of Arkansas Agricultural Experiment Station, *Bulletin No. 458*, 1945.

TABLE 17.—EFFECT OF STORAGE ON THIAMINE IN RICE

Variety and Type of Rice	Thiamine	Thiamine after 3 Months (71°–76°F)	Loss
	<i>Micrograms/gram</i>	<i>Micrograms/gram</i>	<i>Percent</i>
Fortuna			
Paddy	3.07	2.98	2.93
Husked			
First break	1.34	1.26	6.00
Second break	1.20	1.08	10.00
Milled white	1.00	0.88	12.00
Zenith			
Paddy	3.06	3.03	1.00
Husked	3.31	3.11	6.00
First break	1.34	1.14	14.80
Second break	1.25	1.08	13.60
Milled white	0.77	0.70	9.00
Nira			
Paddy	3.70	3.60	2.70
Husked	4.10	3.93	4.14
First break	2.25	2.04	9.33
Second break	1.59	1.42	10.70
Milled white	1.00	0.92	8.00
Prelude			
Paddy	3.56	3.48	2.25
Husked	3.84	3.66	4.68
First break	1.40	1.26	10.00
Second break	1.12	1.02	7.14
Milled white	0.84	0.80	4.76

SOURCE: M.C. Kik and R.R. Williams, *The Nutritional Improvement of White Rice* (National Research Council, Bulletin No. 112), 1945.

TABLE 18.—EFFECT OF CONVERSION ON BREAKAGE IN SHELLING

Batch Number	Variety	Treatment	Whole Kernels	Broken Kernels	Yield Head Rice	Total Yield
			<i>Percent</i>	<i>Percent</i>	<i>Pounds</i>	<i>Pounds</i>
304	Rexoro	raw	61.0	13.5	82.4	108.0
304	Rexoro	converted	72.5	4.0	97.8	110.0
301	Nira	raw	47.0	21.5	69.8	103.0
301	Nira	converted	71.0	2.5	95.8	107.0
303	Rexoro	raw	60.5	15.0	81.6	108.0
303	Rexoro	converted	73.0	4.5	98.5	111.0
305	Rexoro	raw	61.5	12.0	83.0	107.0
305	Rexoro	converted	70.5	4.0	95.1	108.0
543	Nira	raw	58.5	19.0	80.1	111.6
543	Nira	converted	72.0	3.5	97.2	108.7
544	Nira	raw	47.5	29.5	70.3	111.6
544	Nira	converted	72.5	5.0	97.8	111.6
540	Nira	raw	54.0	22.0	76.1	110.2
540	Nira	converted	73.0	3.5	98.5	110.2
581	Nira	raw	54.5	22.0	76.8	110.2
581	Nira	converted	75.5	3.0	101.9	113.1
566	Rexoro	raw	43.0	35.0	65.3	113.1
566	Rexoro	converted	74.5	3.0	100.5	111.6
699	Rexoro	raw	63.5	15.0	85.7	113.1
699	Rexoro	converted	75.5	3.0	101.9	113.1
706	Rexoro	raw	67.0	13.0	90.4	116.0
706	Rexoro	converted	76.0	3.5	102.6	114.5
704	Rexoro	raw	64.5	16.5	87.0	117.4
704	Rexoro	converted	75.5	3.5	101.9	114.5
702	Rexoro	raw	59.0	19.0	80.2	113.1
702	Rexoro	converted	77.0	3.0	103.9	116.0

SOURCE: M.C. Kik and R.R. Williams, *The Nutritional Improvement of White Rice* (National Research Council, Bulletin No. 112), 1945.

TABLE 19.—EFFECT OF COOKING ON THE NUTRIENT CONTENT
OF ARTIFICIALLY ENRICHED RICE

Sample	Thiamine	Loss	Niacin	Loss	Ribo- flavin	Loss
	(Micro- grams/ gram)	Percent	(Micro- grams/ gram)	Percent	(Micro- grams/ gram)	Percent
Hoffmann-La Roche						
Before cooking	5.44	—	44.15	—	2.60	—
Washed three times ¹	5.01	7.90	40.13	9.10	2.51	3.45
Cooked in double boiler ²	5.27	3.12	43.35	1.81	2.53	2.68
Cooked in open vessel ³	4.66	14.33	36.25	17.90	2.31	11.15
Fieger						
Before cooking	4.72	—	46.00	—	—	—
Washed three times ¹	4.08	13.50	39.50	14.1	—	—
Cooked in double boiler ²	4.41	6.40	44.00	4.3	—	—
Cooked in open vessel ³	2.40	49.10	29.30	36.30	—	—

¹One cupful of rice is covered with one cupful of water, stirred, and drained. This is repeated twice.

²One cupful of rice and one and one-half cups of boiling water are placed in the top of a double-boiler. All the water is absorbed and the cooked rice is not rinsed.

³One cupful of rice is placed in an open vessel with 10 cupfuls of boiling water, cooked, placed in colander, and drained.

SOURCE: M.C. Kik and R.R. Williams, *The Nutritional Improvement of White Rice*, (National Research Council, Bulletin No. 112), 1945.

TABLE 20.—CALORIES AND PROTEIN FROM PREWAR FOOD SUPPLIES
(per head per day at the retail level)

Area	Calories per Day							Grams Protein per Day				
	Total Calories	Cereals	Roots and Tubers	Sugar	Fats	Pulses	Fruits and Vegetables	Meat	Milk	Total Protein	Animal Protein	Vegetable Protein
Eastern Asia:												
Manchuria.....	2557	2002	40	32	72	289	44	66	12	88	5	83
Japan.....	2268	1559	157	163	41	147	83	107	11	67	12	55
China.....	2201	1552	112	14	133	260	35	95	—	68	5	63
Formosa.....	2153	1091	434	77	133	102	74	240	2	52	14	38
Korea.....	1904	1419	52	15	72	191	44	106	5	70	15	55
Indian Peninsula:												
Ceylon.....	2167	1289	34	140	142	403	51	63	45	51	11	40
India.....	2021	1306	37	163	71	210	41	37	156	56	9	47
Southeast Asia, Mainland:												
Burma.....	2349	1589	82	103	184	97	62	203	29	73	32	41
Malaya.....	2337	1577	146	100	178	101	66	119	50	57	14	43
Siam.....	2173	1341	200	69	180	114	66	179	24	58	21	37
Indochina.....	2127	1386	143	63	184	96	66	165	24	55	17	38
Southeast Asia, Major Islands:												
Java and Madura...	2040	1154	490	46	61	178	72	35	4	43	4	39
Philippines.....	2021	1115	264	124	130	79	23	218	68	55	25	30

SOURCE: FAO, *World Food Survey*, Washington, 1946.

TABLE 21.—CALCIUM, RIBOFLAVIN, AND OTHER NUTRIENTS
IN AN “IMPROVED” RICE DIET COMPARED WITH
“RECOMMENDED ALLOWANCES”¹

Food	Quan- tity	Cal- orie Values	Pro- tein	Fat	Cal- cium	Vit. A	Thia- mine	Ribo- flavin
	<i>Gr.</i>	<i>Cal.</i>	<i>Gr.</i>	<i>Gr.</i>	<i>Mg.</i>	<i>I.U.</i>	<i>Mg.</i>	<i>Mg.</i>
Rice (home-pounded undermilled, or par- boiled).....	500	1,750	40	10	50	—	1.2	0.5
Roots (sweet potato)..	150	180	3	1.5	30	(²)	0.15	0.1
Pulses ³	60	180	14	0.5	36	—	0.10	—
Meat and Fish (fresh).	40	70	7	5	5	—	0.04	0.1
Vegetable Oil.....	20	180	—	20	—	—	0.15	0.25
Vegetables ⁴	75-150	50	4	—	200	8,000- 15,000	—	—
Fruits ⁵	100	50	—	—	—	—	—	—
Sugar.....	10	40	—	—	—	—	—	—
Total (“Improved Diet”)....		2,550	68	37	320	—	1.64	0.95
“Recommended Allowances” (70 kg. man).....		2,500	70	—	800	—	1.2	1.6

¹Calculations of nutrient content are based on the tables of B.S. Platt.

²Some 6,000-10,000 I.U. of vitamin A would be supplied by yellow sweet potatoes.

³Fieldbeans (*Dolichos lablab*) have been taken as the basis of the calculation.

⁴Including at least 100 grams of green leafy vegetables.

⁵If these are yellow (papaya, tomato, mango, certain bananas) they will provide considerable additional quantities of provitamin A.

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